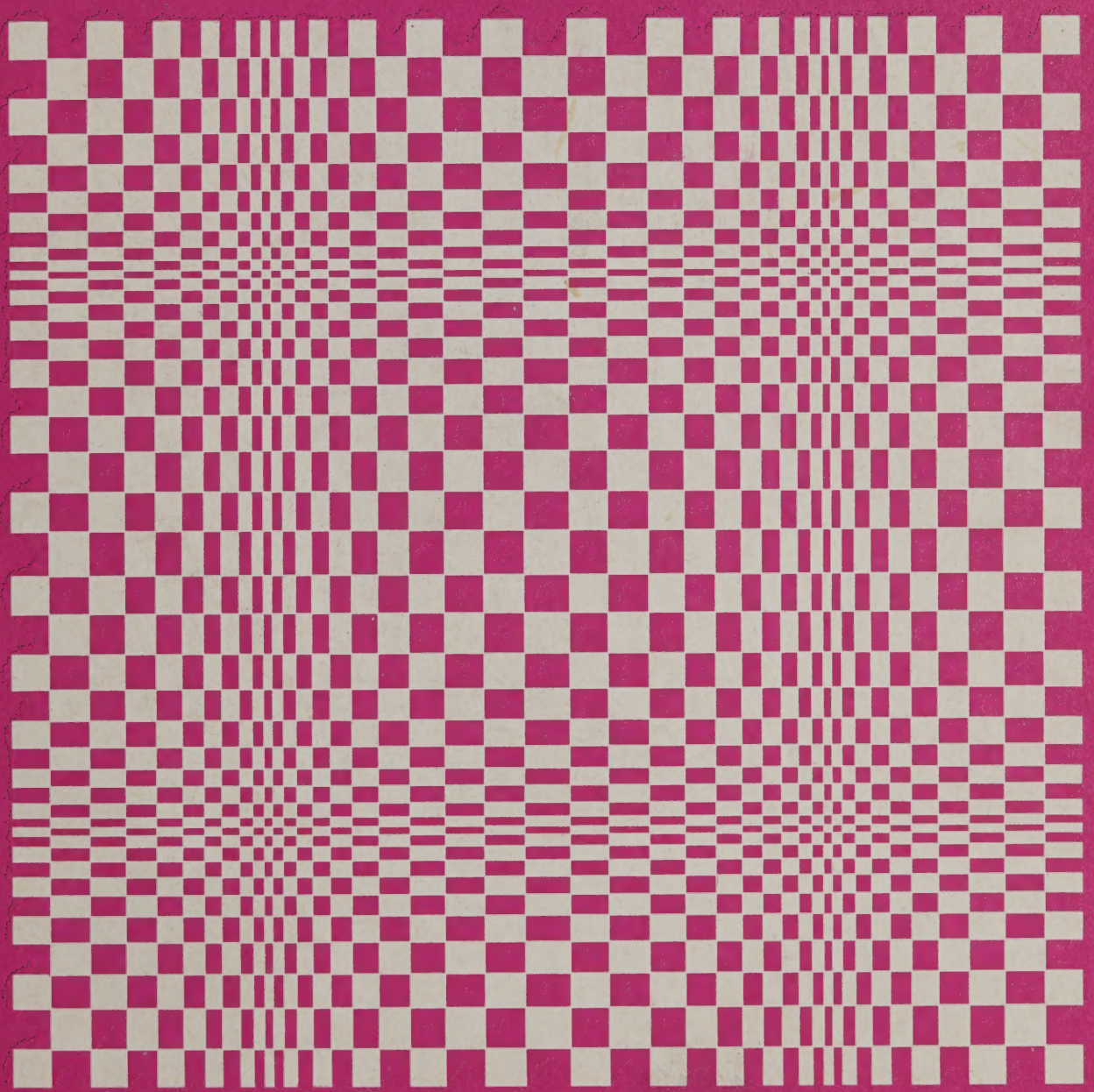
SYSTEMS

PROCEEDINGS

OF THE SECOND

BOSTON ARCHITECTURAL CENTER

LECTURE SERIES 1968



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INTRODUCTION

The Lecture Series on "Systems" was held at the Boston Architectural Center in the spring of 1968. In reviewing the transcript recently, the original remarks came through as yet undated and currently valid. For that reason, the Center decided to publish this edited copy with the hope that the record which follows will be of value.

Buckminster Fuller sees a general theory of systems as one in which man coordinates his knowledge to accomplish a specific set of goals. It is a total philosophical system encompassing the complexities of society, religion, and the economics of wealth. Of interest is a parallel he draws between the great masters of technology historically--early sea venturers and explorers and, later, the institutionalized navies of various nations--who utilized science and rational systems to control the forces of nature at sea in order to dominate the destinies of people on land. "Those who stayed on top of the waters and prospered did so because they organized their available knowledge into what is really general systems theory; i.e., they had comprehensive capability. They were just the antithesis of specialists. They had high proficiency in dealing with celestial navigation, the storms, the sea, the men, the ship, economics, biology, geography, history and science. The wider and more long-distanced their anticipatory strategy, the more successful they became."

Fuller on wealth: "... our organized capability to cope effectively with the environment in sustaining our healthy regeneration and decreasing both the physical and metaphysical restrictions on the forward days of our lives."

Fuller on Utopia: "... we can... assume that by the twenty-first century either humanity will not be aboard Spaceship Earth, or, if approximately our present numbers as yet remain aboard, that they then will have recognized and organized themselves to realize effectively the fact that humanity can afford to do anything it needs and wishes to do and that it cannot afford anything else."

"... Earth-planet based humanity will be physically and economically successful and individually free in the most important sense. While all enjoy total Earth, no human will be interfering with another and none will be profiting at the expense of another. Humans will be free in the sense that 99.9 percent of their waking hours will be freely investible at their own discretion. They will be free in the sense that they will not struggle for survival on a "you" or "me" basis and will therefore be able to trust one another and be free to cooperate in spontaneous and logical ways."

Fuller on God: "I think it is very significant that there is no instruction book for successfully operating our ship. In view of the infinite attention to all other details displayed by our ship, it must be taken as deliberate and purposeful that an instruction book was omitted.

Lack of instruction forced man to find that there are two kinds of berries - red berries that would kill him and the other red berries that would nourish him. And he had to find out ways of telling which was which berry before he ate it or die. So mankind was forced because of the lack of an instruction book, to use and develop intellect."

John Nash defines systems as analyzing the problem to determine just what it is we want to do and then organizing all of factors that are involved in the solution of the problem. If there are alternative ways of doing things, they must be compared and evaluated on the basis of cost, schedule, performance, etc. he uses the example of the Polaris System which has a very clear goal--to launch a rocket from a submarine at a target 2,000 miles away.

Unfortunately, it is difficult, if not impossible, to state equally as clearly our goals for achieving environmental quality. How do we build-in unmeasurable values? Do we forget them if they can't be compared and evaluated on the basis of cost, schedule and performance?

John Eberhard provided a delightful talk which was well received by the audience and I believe it comes through in the transcript which follows.

He defines systems as a noun and as a verb. He also includes six steps in systems analysis from one: a statement of the problem - to six: an analysis of the solution, that is worthy of the attention of the reader.

In discussing the limitations of applying resources to problem solving and expecting immediate results, he points out that to solve the problem of technology of housing does not mean simply pouring in "lots of money;"but, in order to solve problems of such magnitude, society will have to develop new institutions.

Exra Ehrenkrantz, like Bucky Fuller, refers to other fields of construction to demonstrate the antiquity of present building construction methods. "... if airplanes were designed and produced by taking the low bid for the assembly of a lot of different components, the engines, the fuselage, et cetera, from a group of different subcontractors and assembling them at the airport, probably none of us would enter an airplane designed and produced under these circumstances. However, we really need not worry because it wouldn't get off the ground."

Ehrenkrantz as well as Eberhard understands that industry's interest is in the size of the market; it has to be large enough to merit industrial investment in testing research in order to come up with new products. Both foresee the government's present involvement in Operation Breakthrough and its role in market aggregation.

Wilbur Larkin observes that SCSD accomplished two things: "First, it started the architect, the engineer and the construction industry all working and thinking together on the pre-planning of a complete building, which resulted in the development of new construction products not previously available. And, second, it furthered the cause for performance specifications."

Larkin sees architects in the future as working for large construction and building systems firms, and as working less for a specific client on a specific project.

Bill LeMessurier says a good building system has: 1) a relationship to its time and place; 2) some degree of dimensional standardization; and 3) an idea for making joints. His presentation is based on his personal experience with the Pittsburgh High School System Development.

Moshe Safdie sees building systems as an approach or an attitude to the technical method of construction, "... a systematizing of the process of construction." It is not the increasing numbers of population alone, but the rate of increase in construction that will be required to meet this population increase, that leads us to systems or systematized building.

Safdie's city of the future will consist of a sub-division of spaces rather than a sub-division of land, not with individual buildings, but with a continuous building. He believes that attempts to develop open systems will involve complex dimensional coordination that the industry cannot meet at present or in the near future. For him, closed systems are easier and less complex and are capable of present industrial accomplishment. He believes that the ultimate solution is to first develop closed systems and that they, in turn, will lead to the development of successful open ones. He also expressed concern for the design process that leads to industrialized forms--what do these environments turn out to be when all the technology has ultimately been applied?

The "Systems" Lecture Series is grateful to George Macomber of George B. H. Macomber Construction Company, who chaired the Lecture Series and whose time, energy and talent helped to make it a success. The conception of the Series and the selection of speakers was largely due to Marvin Goody and Irving Salsberg, two dedicated architects in the Boston community.

A great part of the editorial work and coordination of the publication is due to the talent of Pat Wells.

Sanford R. Greenfield, FAIA
Director of Education
Boston Architectural Center

PHILOSOPHY, INVENTION, EXPERIENCE

R. BUCKMINSTER FULLER

Richard Buckminster Fuller, professor, architect, philosopher and inventor, is President of Geodesics, Inc. (Cambridge,Mass.) and Plydomes, Inc. (Des Moines, Ia.); Chairman of Tetrahelix Corporation (Hamilton, Ohio), and Professor of Design Science Exploration at Southern Illinois University. He is Director of Temcor Corporation (California), Vice President of the World Society of Ekistics, Architect/ Trustee for "Denationalized World Man Territory" (Cyprus). He has served on the International Advisory Council of the National Pollution Control Foundation, and on the Committee of Human Ecology at the Institue of Human Ecology in Illinois.

He is the inventor of the Dymaxion System, the Geodesic Dome, the Octet Truss, the Plydome, the Submarine Island, Tensegrity structures, the Laminar Dome, the Aspension building and the Monohex Geodesic.

R. BUCKMINSTER FULLER: I don't know whether I am really a good selection to start off your series because, although I have been using general systems theory in my own life for a very long time, in order for me to be absolutely faithful in talking about it, I shall have to talk about what may in some instances seem pretty remote to you. However, I would like to give myself the challenge of really talking to you in terms equitable to those I use myself regarding general systems theory, hoping that this will open up a very big horizon at the start for you as it did for me.

The phrases "general systems theory" and "systems analysis" seem quite new to most people. I think Ludwig Von Bertalanffy, the great biologist, was the first to ever coin the phrase "general systems theory." As a biological scientist, Von Bertalanffy was interested in the ecology of living systems and discovered that there were comprehensive system behaviors in nature unpredicted by the behaviors of the systems' components, a phenomenon known to scientists as synergy. Von Bertalanffy, along with other mathematicians who had discovered synergy in the theory of games, etc., began to discover that there were complex patterns which could never be apprehended, understood, operated on, or dealt with if we approached them only in terms of their separate elements; that is, literally in an elementary manner.

In 1961 at the World Affairs Conference at the University of Colorado, Ludwig Von Bertalanffy and I were brought together for a series of panel discussions. During the week of our meetings, we both explored our ways of discovering and using general systems theory and agreed that what we were dealing with was exactly the same phenomenon although we came at it really very differently. Von Bertalanffy employs his general systems theory subjectively. He agreed with me that my comprehensive anticipatory design science is an objective employment of systems theory and that I had discovered that same phenomenon through completely different circumstances.

I first learned what was to be later called General Systems Theory at Annapolis in 1917. I went to the U. S. Naval Academy at the moment in World War I when the grand masters of the world and the British Navy, the "ins" were challenged by the "outs" and for the first time in history had to acknowledge the American Navy as an equal and give it great support or else the old masters were probably going to lose their world mastery. As a consequence the British Navy began to disclose to the U. S. Navy some of the inner secrets of its grand strategy. Much that was of basic strategic significance was disclosed to the young men who were being trained at the U. S. Naval Academy at that moment. We learned grand theories as well as special strategies used by the old masters.

The old masters had commanded that the highest economic priority go towards objectively using everything from all the scientific findings of all men and all history, all put to highest advantage to produce weapon carriers to carry ultimately the greatest hitting power the greatest distance in the shortest time, firing with the greatest accuracy and with the least effort. They needed, in effect, the greatest tool with which to master the Earth inasmuch as there can exist really no worthwhile second place navy. Navy represented the focused objective for application of all that man knew because of the simple fact that you could carry bigger guns on ships than you could pull over land with horses. All science was reduced to versatile mobile practice in the navy. Armies and fortresses were static and good for local war. Navies were the dynamic and inherent world tools up to and throughout World War I.

In sending the navy off to the high seas with all the nation's most important hardware, the nation had to develop navy men whom the old masters could not only count on to be their most competent right hand men but who could also be trusted with competent command and maintenance of this most powerful tool even when out of sight of the old masters. They had to be men who understood world economic patterns as well as did the old masters themselves. These men had to be capable of taking a great navy half way around the world from home bases, building a new naval base--say in South America or in any other remote place--understanding technology in every way, handling thousands of men, millions of dollars, thousands of technical and psychological and economic problems--in other words, they had to be very comprehensive men.

The training scheme in the navy was to pick the brightest men and send them first over to the Bureau of Ships where they could learn the theory and history of ships themselves and their great comprehensive patterning. Then the naval department deliberately rotated their officers' services, sending these men alternately to sea on different types of ships--every type and kind: submarines, battle ships, destroyers, supply ships and airships. Between ship assignments, the navy rotated its line officers into naval stations around the world. They rotated them back and forth, out of the ships into jurisprudence, into managing great naval shipyards which had the most powerful industrial tools of those days, and then to foreign embassies to get world statesmanship experience, and finally into the comprehensive world strategy studying at the Naval War College. In this way, these men became thoroughly versed in general systems theory which also means an identification of navy as a comprehensive design problem.

I would like to point out here that although three-quarters of the Earth is covered by water, 99.9 percent of humanity lives on dry land distributed in small increments isolated in remote parts of the globe. In contradistinction to the comprehensive knowledge used by the man of the sea, historically we can say that average human beings, throughout pretwentieth century history, had each seen only about one-millionth of the surface of their Earth. The small isolated groups of humanity were utterly unaware of one another's existence. They were everywhere ignorant of the vast variety of very different environments and resource patterns occurring other than where they dwelt.

Different were those few human beings who gradually, through a process of invention and experiment, built and operated first the local river and bay, next along-shore, then offshore rafts, dug-outs, grass boats and outrigger sailing canoes. Finally they developed voluminous rib-bellied fishing vessels and thereby ventured out to sea for progressively longer periods. Developing ever larger and more capable ships, the seafarers eventually were able to remain for months on the high seas. Thus these venturers came to live normally at sea. This led them inevitably into world-around, swift, fortune-producing enterprise. They thus became the first world men.

The men who were able to establish themselves on the oceans also had to be extraordinarily effective with the sword upon both the land and sea. They had to have great anticipatory vision, great ship designing capability, original scientific conceptioning, mathematical skill in navigation and exploration techniques for coping in fog, night and storm with the invisible hazards of rocks, shoals and currents. The great sea venturers had to be able to command all the people in their dry land realm in order to commandeer the adequate metal-working, wood-working, weaving and other skills necessary to produce their large, complex ships. They had to establish and maintain their authority in order that they themselves and the craftsmen preoccupied in producing the ship be fed by the food producing hunters and farmers of their realm.

There were very few men who went to sea and became top power men But as they went on their sea ventures, they gradually found that the waters interconnected all the world's lands and peoples. They learned that the people in each of the different places visited knew nothing of people in other places.

The great venturers found resources of the Earth very unevenly distributed and also discovered that by bringing together various resources occurring remotely from one another, one complemented the other in producing tools, services and consumables of high advantage and value. Thus resources in one place which previously had seemed to be absolutely worthless suddenly became highly valued. Enormous wealth was generated by what the sea venturers could do in the way of integrating resources and distributing the products to the amazed and eager customers everywhere around the world.

The ship-owning captains found that they could carry fantastically large cargoes on their ships, due to their floatability--cargoes so large that they could not possibly be carried on the backs of animals or men. Furthermore, the ships could sail across a bay or sea, travelling shorter distances in much less time than it took to go around the shores and over intervening mountains. So these very few masters of the water world became incalculably rich and powerful.

Not only were the knowledge levels of the seafarers and land dwellers in sharp contrast, but also the expression of this knowledge within their respective programs for survival and the technologies organized for the successful completion of their differing programs. Man on the land started off completely ignorant, not really knowing which foods he could eat: what would kill him and what would support his regenerative needs. The people who were able to find what they had learned would keep them going were relatively few in comparison to the total numbers of humanity. There were enormous numbers who were not successful.

When man on land found a place where he could survive well, he tried to guard it, because there seemingly was not nearly enough vital sustenance to go around. For this reason "have-not" people were bound to come around who would frequently try to displace him. So the successful land people built great walls, like the China Wall and, later, smaller walls which they used as fortresses. Their thinking was that the heavier and thicker and higher the wall, the more secure they felt. Inside these walls were fresh water wells and saved food stored in graineries. When the enemy came around, the defenders took everything fresh from the fields to within the walls, leaving nothing for the attacker to eat. The general system was to wait until the attacker was weak and starving and then go out from the walls and overcome him. The security of man on the land was placed primarily in heavy walls and constructing fortifications "strong as the rock of Gibraltar." It was a philosophy of more with more: the bigger the wall, the bigger the grainery, the bigger the sword, the bigger man's sense of security.

The logic of the evolution of the technology of the sea was entirely different. There are very few who really understand the grand strategies of the sea vessel evolution. In order to be able to stay on the sea, the ship has to float. A stone ship will not do. As Archimedes showed, we can only float as much weight as the weight of the water the ship displaces. Therefore, in designing the ship, there is a specifically limited amount of weight to invest in each of the ship's many and varied essential functions.

It is of course of prime importance to invest certain amounts of the total displacement weight in the structural strength of the ships themselves and in their means of propulsion. It is also necessary to invest a certain amount of displacement weight in the carrying of the fuel, and in the carrying of foods for the crew. It is essential to invest in a large amount of cargo space (and therefore of additional weight) to make the contingency of such two year or longer trips worthwhile. It was often fundamental to invest in cargo capacity for replenishment and improvement of the home-ports' ship-building industry resource, as well as to invest in cargo capacity for munitions and guns to protect the ship.

The latter investment became of progressive necessity, so great that separate escorting ships had to be built as the wealth generated by sea commerce brought the world battling for high seas domination to a point where the gun batteries became greater than those of the land fortresses and were floated in fast maneuvering ships. Men did not go to sea defensively. They went offensively to make a fortune winning voyage. If you had more powerful spars and could drive your ship a little faster, if you had stronger fibres in your ropes and sails, you could cope with greater winds and you could out-maneuver the other pirates and could become master of the sea.

So there was great competition on the sea to do more with less. As men became informed by their high seas experiences, they built continually improving ships, by continued improvement of the ratios of invested resources of weight and energy and time per given functions of essential ship performance requirements. This was in contrast to competition on the land where land dwellers were trying to do more with more.

Building technology on dry land has never been predicated upon total weight limitation: Architects do not think in terms of weight of their buildings nor in terms of performance per pound and energy expenditure ratios. Most of man's important early buildings were fortresses or temples. Extra weight gave the promise of long lasting security.

For the reasons I have given you, our dry land building arts have never been based on ratioed performances per pounds of invested resources. For these reasons, we do not even think of our buildings in terms of weight. Can anyone in this audience tell me what this new 52-story building over there weighs? (No hands) Can Mr. Cascieri tell me what the building weighs? (Laughter) Do any of the architecture students here know what this building weighs? Can anyone in the audience tell me within 100,000 tons what this building weighs? (Laughter)

Can anyone in this audience tell me what the Queen Elizabeth weighs? I am sure many of you can: Yes, 85,000 tons. People have a pretty good idea of performance per pound in relation to sea and air structures, but do not think about it in relation to land structures. But historically, on the sea there has always been this grand strategy of ephemeralization or doing more with less. There is no class in economics teaching it, however, and the U. S. Congress doesn't think that way, and it is current to hear that you "can't pull yourself up by your boot straps". Doing more with less means that you can.

The men who have always been doing more with less, those comprehensively informed master venturers of history who went to sea, soon realized that the only real competition they had was that of other powerful outlaws who might also know or come to know through experience the real grand strategies. I call these sea mastering people the great outlaws or great pirates, simply because the arbitrary laws enacted or edicted by men on the land could not be extended effectively to control humans beyond their shores and out upon the seas. So the world men who lived on the seas were inherently outlaws and the only laws that could and did rule them were the natural laws: those physical laws of the universe which when tempestuous were often cruelly devastating. High seas combined with nature's fog and night hidden rocks were uncompromising.

And it followed that these great pirates came into moral battle with one another to see who was going to control the vast sea routes and eventually the world. Their battles took place out of sight of landed humanity. Most of the losers went to the bottom utterly unbeknown to the historians. Those who stayed on the top of the waters and prospered did so because they organized their available knowledge into what is really general systems theory; i.e., they had comprehensive capability. They were just the antithesis of specialists. They had high proficiency in dealing with celestial navigation, the storms, the sea, the men, the ship, economics, biology, geography, history and science. The wider and more long-distanced their anticipatory strategy, the more successful they became.

Secrecy was, of course, of the essence. If the other powerful pirates did not know where you were going nor when you had gone nor when you were coming back, they would not know how to waylay you. Because of the curvature of the Earth, another ship over fourteen miles away is out of sight below the horizon. This was the distance at which a ship could be stalked. If anyone knew when a ship was coming home, it could be stalked and waylayed. "Small-timers" could come out in small boats and waylay a

ship tiredly coming home after a two-year treasure harvesting voyage. Thus hijacking and second-rate piracy became rampant around the world's shores and harbors. And secrecy became the essence of the lives of the successful pirates - ergo how little is know today about what I am here relating to you.

The topmost great pirates soon discovered, both in their long distance planning and in their anticipatory inventing, that the grand strategies of sea power made it experimentally clear that a plurality of ships could usually outmaneuver one ship. So the great pirates invented navies. Then, of course, they had to control various resource supplying mines, forests and lands with and upon which to build the ships and establish the industries essential to building, supplying and maintaining their navies' ships.

You may ask, "Aren't you telling us about the 'British Empire'?" And I answer, "No!" The so-called "British Empire" was a manifestation of the world-around misconception of who "ran things" and a disclosure of the popular ignorance of the great pirates' absolute world controlling through their local stooge politicians, sovereigns, prime minister, et al, as only innocuously and locally modified here and there by the separate sovereignty's internal democratic processes.

The British Isles, lying off the coast of Europe, constituted a fleet of "unsinkable ships" and naval bases controlling and commanding all the great harbors of Europe. Those islands were the possession of the topmost pirates. Since the great pirates were building, maintaining and supplying their ships on those islands, they also logically drew their crews from the native islanders who were simply shanghaied, seized or commanded aboard by imperial edict.

Seeing these British islanders aboard the top pirate ships, the people around the world mistakenly assumed that the world conquest by the great pirates was a conquest by the will, ambition, and organization of the British people. Thus was another of the great pirates' grand deceptions victorious. But the people of the British Isles never had the ambition to go out and conquer the world. As a people they were manipulated by the top pirates and soon learned to cheer as they were told of "their nation's" prowess.

Here I would like to point out that the top pirates, the "in" pirates, had to think in terms of the whole world, and their planning and thinking had to be what I call "anticipatory" in that it had to be in terms of many years ahead. Such projects as looking for and finding the northwest passage were part of a hundred year plan for their operation of their navy. This is the beginning of a realistic application of general systems theory, one of the valid legacies of the great pirates. They called it grand world strategy. They used it to integrate all the variable factors of their world-around enterprise operations and to exploit all the cumulative knowledge of all men in the development of their world mastering tools.

In exploiting cumulative knowledge, the great pirates patronized and, so, eventually inslaved scientists. The "in" pirates had come in and gotten way, way ahead of the "out" pirates because they listened to the scientists who advised them to steam drive their navies and not wait for the wind to fill their sails. The metallurgical, chemical and thermodynamic bases of the invention of the steam engine were implicit in the chemical conceptioning of Lavoissier. As an indirect recognition of his general integrity, he was guillotined.

With steam driven ships came vast acceleration of world commerce and, with it, still more enormous amounts of wealth. Realizing for the first time in history that great wealth accrued to scientific discovery, the great pirates put up large amounts of their wealth for further scientific discovery. This was the beginning of the Royal Society in England and brought great scientific competition to determine who would run the world with the new steamships. Out of this competition came the suggestion that a steam driven ship can be driven harder through the sea and carry still more cargo if it were made out of metal. Soon the "in" pirates were moving away in their metal steamships even faster from the "out" pirates in their wooden ships.

The logistics inherent in the building of metal ships introduced the pirates to a great new phase in their development: The resource organization to produce the metal-blast furnaces which were the beginning of world industrialization with metal and its essential historical correlation - the railroad. The building of wooden ships could be done pretty well right at the shore, but the building of metal ships required the development of the railroad out of ocean steamer technology. Seagoing technology went up on the land onto steel rail canels. By principle, they brought up onto the land their ship masts, yardarms and lifting tackle which have also become our cranes and winches to build bridges and great buildings, as well as the ships.

A marine railway must both support during the building as well as move enormous ships. During construction there must be the most even as possible distribution of concentrated loads on the keel through balanced shorings. These shorings are snow shoed at the points of load transfer to the earth to prevent sinking. A marine railway is designed with a pitch so that the ship will slide rapidly into the sea and not fall over into the sea. Once in the sea, the once concentrated loads of the shorings on the keel become, through hydraulic pneumatics, evenly distributed loads for which the ship is designed. Once in the sea, a ship's keel will only encounter concentrated loads through the disasters of sailing onto the rocks or ramming another ship.

When the marine railroads backed onto the land to bring back enormous loads of coal and iron, they distributed the load onto two rails and the engines were steam driven. Their eventual ability, demonstrated most dramatically by the American transcontinental railroads, to transport unprecedented tonnages formerly

carried only on water was recognized by Sir Halford Mackinder, the English political geographer, as tantamount to converting the dry lands to the functions of oceans. This concept formed the nucleus of up through World War II mechanized warfare and automatically precipitated a reassortment of world economic and military factors. All of this is a logical development from sea going technologies and so at the historical inception of the railroad, it is not surprising to find such men as Telford building the railroads, tunnels and bridges of England as well as the first steamship.

And other technologies developed first for the great pirates' navies gradually came to augment man's advantage on the land with, of course, added economic gain for the great pirates. It happened slowly: Steel was produced for ship building fifty years before it was ever used in a building on the land. The great electric dynamos were first produced for ships and when they were all supplied, finally the dynamo manufacturers began to sell them to people on the land to give domestic light. Refrigeration was developed and in use on big ships sailing the sea so that a navy could preserve its food and stay out there longer to outmaneuver the other pirates. Thirty years later it was available for land use. Desalinization has been central to man's success on the sea for one hundred years: We could not have a steamship without desalinization. All the technology which is now benefitting man, originally came out of the technology developed for the sea and then, more recently out of aeronautical technologies. It now comes, most importantly, from developments for the space programs.

Thus it comes about that we are now discovering that the prime designers of much of history's comprehensively coordinated world undertakings were the great pirates. Many of their social organization inventions have been employed for so long that they are accepted unthinkingly by society as constituting "the only and obviously natural" way of carrying on life. But many of the value systems as yet used by society - and most deleterious is perhaps that of gold as essential to logical control of the economic initiative - are utterly obsolete and often lethal inheritances from the pirates. Gold was used for trading by the great pirates in lieu of any good faith whatsoever - and in lieu of any mutual literacy, scientific knowledge and intelligence on both sides of the trading.

From the picture I have been drawing for you, you can understand that suddenly the pirates were making so much money out of the by-products of their undertakings on the land, (money that they never expected to make), that they became intensely interested in land business and commerce. They didn't want to have their gold put into jeopardy; the gold that they used to send around in their ships for trade in foreign countries where nobody would trust them. To buy what they wanted there, gold seemed to be the only medium in which to deal. But since the "out" pirates and other highjackers tried to take their gold away from them, and since they were becoming firmly entrenched on the land, they decided to negotiate agreements with people in the foreign countries wherein they left a hostage there as ambassador. This man's function was to do the bookkeeping for both sides of the trading, thus enabling the pirates, at the end of the year, to simply transfer their gold from one bank in London to another bank in London. Their gold could all stay at home. This was the beginning of the movement of the great pirates going up onto the land, and it is really fascinating to review the data.

I couldn't talk this way a few years ago, but the great pirates don't exist any more. They became defunct in 1929 and actually lost their control because of their winning World War I. To explain their losing of world control through their winning of World War I, I must explain some relational factors between the pirates and advances in the science and new technologies of that period. During World War I the incumbent world masters had been challenged by the organized "outs" who were the competitor commerce group of potential top pirates beginning to put the new potentials of science together faster than the old masters had seen fit to do. The "outs" invented going under the sea to break down the line of supply with marines and going above the earth and sea with the airplane.

The top pirates were being so vigorously challenged by the expansion of war patterns into new dimensions that they were about to be displaced, when suddenly a powerful scientific suggestion was made in England to the high command. A scientist said that there were ways in which the guns that reached the front could be made to last twice as long. He said: "Wouldn't this be as good as getting twice as many guns to the front? That is, even if the line of supplies were being critically slowed down by sinkings, the guns which did reach the front would last twice as long." The old high command said, "This is nonsense, but what do you have in mind?" The scientist answered, "Well, we have had the technology to do this in the drawer of classified, secret information since 1845. It is a chrome-nickel-steel alloy. When it was originally presented to you, it was refused by your short-term thinking which insisted that the quicker metal would rust and be destroyed, the more steel you would sell.

You decided then that it was a dangerous idea and decided not to pay attention to any change the scientists and inventors were proposing."

The pirates never trusted anything they could not see, touch, or smell. They coordinated by virtue of their extraordinary sensorial ability - their historical sea background made them very physical human beings. They could count masts of ships swiftly, they could knock another guy down, they could play beautiful polo and they could sail a very fast yacht. They did things in that sensorial way. But they were suspicious of anything invisible; internal structuring of

alloys were invisible; ergo, they were unaccredited by the old pirates.

At the turn of the century, we were coming to the point where there were x-rays, alloys and other kinds of invisible events found through scientific discoveries, but the top pirates didn't want any of that invisible phenomena let loose. They were suspicious of its portent. They said, "The kind of steel we we are making is good and will do." In America, they already owned U. S. Steel and some of its competition, and were turning out what was called "mild steel." This is not specification steel at all and was the steel of the great rust dumps of pre-World War I. Finally, because of submarine sinkings of their navy, the top pirates, in order to survive, had to allow their scientists to go to work on what was to the pirates, the scientists' own inscrutible terms. Thus in saving themselves, the great pirates allowed the scientists to plunge their grand industrial logistics of support strategy into the vast range of the electro-magnetic spectrum utterly invisible to the pirates.

Thus in World War I, industry suddenly went from a visible to an invisible base, from the track to the trackless, from the wire to the wireless, from visible structuring to invisible structuring in alloys. The big thing about World War I, is that man went off the sensorial spectrum forever as the prime criterion of accrediting initiations.

The great pirates came out of that first World War unable to cope knowledgeably with what was going on in the advanced scientific frontiers of industry. The pirates delegated inspection to their "trouble-shooter" experts, but had to content themselves with relayed second-hand information. This forced them to appraise blindly, ergo, only opinionatedly, whether this man or that really knew what it was he was speaking about. The great pirates could no longer judge for themselves. Thus the great pirates were no longer the masters. That was their end:

The great pirates are now extinct.

As I stated earlier, I was at the Naval Academy at that unique historical moment when the "in" pirates' line of supply was being so badly broken by the "out" pirates' submarine warfare, that whoever could get the enormous industrial productivity potential of the United States on their side would probably be the winner. For this reason, the United States Navy was allowed to draw up to parity with the British Navy. I found in the United States Naval Academy that the authorities were indoctrinating a number of young people to move forward very rapidly during this emergency time. The authorities were deliberately taking the bright young men and setting out to make them into comprehensivists. To understand why this occurred, we must again look at the navy in terms of general systems theory.

The United States Navy, as of World War I, had airplanes, but they were just in their infancy. Navy airplanes patrolled off the European coast looking for submarines, but did not get into much fighting. Our land planes had a limited number of dogfights. But no airplanes had as yet flown over oceans. They were only local tools like landing boats. On the other hand, the navy represented a vast complex of realized technology which represented objective uses of all that man had found out about his physical universe in chemistry, physics, mathematics, geography, geology, biology and others. Navy theory asks, "What" and "Where" are the world's resources? What are the unique performance excellences of each and every chemical element? How do you separate them and then reassociate them to bring about supreme energy controlling capability by which you can run the world realized in floating hardware shops which carry the greatest hitting power to any point on Earth in the shortest time? There again there could only be one top navy - the one that stayed on top of the ocean. Second best navies went to the bottom. Navies as make-believe greats had no meaning whatsoever.

Naval systems theory assumes that the best defense is the supreme offensive capability. Unlike long, drawn-out land warfare's sieges, naval engagements are over in minutes. It takes only minutes to find out who has the supreme hitting power in batteries of big guns which are floated by ships because they weigh too much to be transported over land.

The navy had to develop officers who were capable of taking all that hardware and the multi-thousands of personnel to any part of the great world ocean. With the enormous amount of shop maintenance necessitated by such a task, it was essential that the officers have the scientific, logistical and psychological capability to build great bases anywhere around the shores of the one-ocean world whose three "bays" are the Atlantic, Indian and Pacific. And until 1919, the one-ocean world was "the world."

For a few decades, the fighting-bombing airships took over the world control through domination of the air-ocean world. Since then, supreme control of Earth is in the dynamic balance and dominances won only by superior capability of satellite and planetary maneuvering in major universe. But general systems theory as first conceived in establishment of world navies still governs supreme control systems. In sending your men off around the world in the days of naval supremacy, and in making this great investment in the navy, you had to be reasonably certain that it would be supreme around the world. In order to be able then to have such an extraordinary operation as a world controlling navy, you had to have officers who not only understood a great deal but were also operatively capable of dealing with all circumstances. They had to be comprehensive industrialists in order to be able to build a naval base anywhere around the world - often half ways around the world from home - to rebuild and improve their own ships. They had to have complete knowledge of the history and principles of world economics. They had to understand the ambitions of all the world's nations. They had to have competent capability in philosophy and the history of the development of law and human rights. The navy's

officer training program at that moment in history, was comprehensively specific and always broadening. The comprehensive coordinating capability of the naval officer had to multiply continually.

The navy was the first line of national defense against the exterior forces of destruction. Because the sea covers three-quarters of the earth, the navy had to cover three-quarters of the earth. The navy was inherently world-minded. "Join the navy and see the world" was its enlistment slogan. Early in this twentieth century, came wireless communication by radio with ships half way around the world at sea. But until and including World War I, we didn't dare trust top secret information to the then only thirteen year old and openly tuneable radio. We didn't dare put important secret messages on the air. Strategically vital messages had to be carried by courier, and the courier couldn't get from here to there any faster than you could get a ship from here to there. However, since we didn't dare trust radio with secrets of supreme national strategy, up to and throughout World War I, the naval officers who took the nation's world-commanding navy off to sea had to be trusted not only with the ultimate fate of the nation but also with the protem responsibility of running the world until couriers could be exchanged with the nation's elected leader. To meet this ultimately potential responsibility required the most comprehensively capability obtainable by scientific training and selective promotion. The ship's captains as well as the flotilla, division and fleet admirals had to have complete local autonomy and authority. The captain of the ship had control over the life and death of the personnel on board.

I was brought up in that navy and learned its comprehensivity-breeding educational strategies. After World War I, we found that we could "scramble" the radio so that it was proof against deciphering. We learned much more about electronics. Suddenly, democracy withdrew the autonomy of the captains and commanders of ships and admirals of the fleet. The authority had centralized, in physical fact, into the White House and right up to the President's telephone. There is a widely held misconception that holds centralization of authority to be an arbitrary political volition. Not so. It was a physical communication fact brought about through electronic inventions. Now it is inexorable and exercised officially through laws and unofficially through lobbies.

From 1919 on, the navy too began a depart from comprehensive education towards the specialization which has long been the expression of all other educational disciplines: Navy began to have its naval aviators, submarine men and so forth. I happened to attend the United States Naval Academy at Annapolis and to live through the last, pre-1919 days of naval officer's training in comprehensivity as a discipline carefully developed over centuries and relayed secretly by the British admirality to the U. S. Naval authorities during World War I, as the British Navy found itself inadequate to cope alone with the German's submarine warfare.

I began in 1917 to study these great theories of navy, the development of general logistical support of navies by great nations, and the establishment and maintenance of lines of supplies up to the critical moment of contact, when major naval engagements were decided on the first and second salvos demonstrating indubitably who had the best hardware, a condition that could only be altered by decades of new technology.

I saw that this comprehensivity of the top navy strategist represented great anticipatory design science, enormous vision, and supreme economic-wealth-investing-initiative. I saw that the theory of navy might be identified as a comprehensive design problem. The navy and its industrial and logistic support of 1917 demonstrated well what I mean by comprehensive anticipatory design science. I saw that the matter of finally firing cannons from a moving ship on the heaving sea at another moving ship on the heaving sea represents all the variables that would be operative in firing from any steerable planet against any other steerable planet in the free heavens. All the mathematical complexities of all the variables of the universe were inherent in that problem.

In those days, there were not as yet computer technologies. Into the problems of firing enter all those variables which go way back in time such as the specifications of the ship's steel, the design and strength of the hull and so forth. They must all go into the problem and they are all calculable. These variables have very slow event frequencies as do, for example, how frequently the ship has and will go into drydock. Into the problem must also go those variables with a much higher frequency of events such as the wind, currents, wave heights, speed of the ship, etc. Some have very high frequencies until finally the point of contact with the enemy is approached.

At the point of contact, calculations go from logistics to ballistics, wherein there are interior and exterior ballistics. Interior ballistics have to do with all the variables involved before the gun is fired and exterior ballistics have to do with all the forces and factors, such as gravity and the wind, which operate on the trajectory of that missile after the gun has been fired. For interior ballistics, many of the variables can be listed and calculated well in advance. For this we had "plotting rooms" with enormous, well laid out, beautifully organized formulae, and we knew all the variables involved. We put the information in as quickly as we could and then did long-hand integration of that information with the suitable mathematics. Finally, we would get up to the contact point with the last motions of the ship and the latest bearing of the wind, and the gun would be fired. After that would be the first correction.

I knew that people were trying continually to improve firing techniques, so I began saying that there must be a whole lot of things added which probably don't improve the situation. We didn't dare leave any of

them out because we were not really sure which ones were accounting for accurate firing. I began running these problems in longhand and leaving out one of the factors each time. Sometimes I came out so badly that you might just as well have shot and aimed out anywhere in the sky. If that happened, I immediately put that variable back in. But when I came to the subtraction of a variable that didn't seem to make much difference, I would leave that one out. That variable was redundant.

Finally, I got the number of variables down to what seemed to me to be a minimum-maximum number of factors operable in all fundamental degrees of freedom. This was the beginning of my own personal participation in comprehensive anticipatory design science and general systems theory. In general systems theory, it is very important to begin with the biggest possible picture and then gradually eliminate irrelevancies. It is like playing Twenty Questions: You start with the largest hold you can on the puzzle and ask which half contains the answer. Finding it, you are able to throw out the other half and so on until the puzzle is well defined and without irrelevant elements. How many stages it takes to do this is called in computer language how many "bits". This is what "bits" means in computer work.

After these experiences, I said this special navy logistics and ballistics case might be generalized subjectively into what I call the "comprehensive minimum-maximum family of universally variable factors." These could then be generalized objectively as a comprehensive anticipatory design science which could be applied to any special case such as world naval mastery or world industrialization planning, etc.

I considered it inadequate to apply this science only to the navy, and I intuited that comprehensive anticipatory design science might be applied also to the larger question of how we can make life on earth a general success for all men instead of assuming negatively that success and even prolonged survival were for the rare and fortunate few. It was the work-assumption of all the great nations at that time (and still is) that Thomas Malthus' prediction of "not enough to go around" was right and concomitantly, in the end, there would have to be a showdown to find out who was going to die and die wholesale. Men and nations were always preparing a vendetta. This is why our fathers all had guns and were always wearing them, and before that, men were wearing a sword if they could afford it - otherwise, they carried a bludgeon. Men had to fight their way to security in a hurry while their muscles were still able to make them winners, since the average life span was 27 years. If a man got to be 25 or so, he was already passé and would most likely just rot in the slums.

When I was attending Harvard before World War I, I was told by a man who was a great friend and relative of my father's (my father had died when I was quite young) about Thomas Malthus who in 1810 was a professor of Political Economics for the British East India Company. He was the first economist to get total data from all around the world.

Up to the time of Thomas Malthus, humanity had already seen a great many world empires. But all the pre-sixteenth century great world empires such as those of Ghengis Khan, Alexander the Great, the Ottomans and Rome, were all what I call "flat empires", that is, they were all part of the same pre-sixteenth century cosmology which conceived of the earth as being flat - a great island, apparently surrounded horizontally to infinity by the sea. All the great empires were flat, postage-stamp empires inside the great infinity. All our ancient maps of the world show that flat concept with civilization centered around the Mediterranean Sea, which word means "sea in the middle of land".

And the people, in the time of Alexander the Great or of Ceasar or of Saladin, all thought in that flat way. That is why "simple, elementary, plane geometry" is used and taught to beginners and "solid" considered more difficult and "spherical trigonometry" even more advanced and more difficult.

When you think about the real consequences of that psychologically, philosophically and mathematically, it is devastating. It means that "inside" the empire, we have something we call civilization while "outside" the empire begins the unknown wilderness with pretty rough people and outside of that, live dragons and beyond the dragons, flat infinity. What we have in flat lands is an only local finiteness, while all outward around the known land extends a flat infinity. This lead the Greeks, in attempting to communicate their mathematical conceptioning, to define the circle as "an area bound by a closed line of equal radius from one point," or a triangle as "an area bound by a closed line of three angles, three edges and three vertexes." The Greeks considered only the area that was "bound" to have validity, finiteness and identity. To them, on the outside of that bounding line existed only treacherous terrain leading outward to infinity and therefore "boundless."

This has had a tremendous feedback effect and explains many ingrained fundamental biases in our present thinking. We tend to think only of one side of a line as definable, organized and valid. "Our side" is natural, right and God's country while the outside has none of these qualities. All humanity has been conditioned to accredit only its own local area of experience as being the natural and logical prototype of all that is good and acceptable: All else is remote, hostile, treacherous and infinite. Infinite systems may contain an infinity of variables. The ancient world was imaginatively controlled by an infinity of gods.

The British Empire, the empire of the great pirates, was the first empire to occur after man knew that the earth was a sphere. A sphere is a mathematically finite or closed system. It is an omni-symmetrical closed system. A sphere is finite unity. Thomas Malthus was the first economist ever to receive all the vital statistics and economic data from a closed system world. Once the world is conceived of as a sphere and finite, there are no longer an infinite number of varying possibilities identifiable uniquely as whims of gods.

Because earth had been discovered by its high-sea masters to be a closed and finite system, the great pirates who controlled the seas took their scientists around the world to discover and disclose to them its exploitable resources. Only because the earth constituted a closed system could the scientists inspect, in effect, all the species and only thus was Darwin able to develop the closed system theory of the "evolution of the species." Such a theory could not have existed before that. It would have had to include dragons and sea-serpents. All the people in all the previous open-edged empires lived in a system within whose bordering infinity, anything could happen. Paganism, in this light, wasn't illogical. The pagans could have any number of gods because any kind of god might exist in boundless infinity. Also, there were an infinite number of chances of upsetting the local pattern. This could be a most satisfying idea, particularly if it happened that an individual didn't like the prevailing local pattern.

Thomas Malthus discovered that man was multiplying himself at a geometrical rate while producing food and other goods to support himself only at an arithmetical rate. For approximately a century and a half, the world mastering ventures "classified" Malthus' books as secret information belonging exclusively to the East India Company. Once classified, that kind of information leaked out only amongst the pirates and scholars. Then Karl Marx, the great pragmatic ideologist scholar, studying in England, encountered the Malthusian data. It was equally clear to Marx that there was not going to be enough to go around. Marx said, "Since there is not enough to go around for all and not even enough to go around for many; certainly those few who are arbitrarily favored by the prevailing system and thereby enabled to survive ought to be the ones who are the most worthy." Obviously, to Marx, those who do the work are the most worthy.

Those who opposed him said that work and daring enterprise alone could increase abundance and support more people. Therefore the enterprisers should be conceded to be the exclusive few who could and should survive. Others said that it should be the bright ones, who by their superior intellectual fitness alone could increase that segment of humanity that would survive. The choice of "who" should survive has always been the underlying basis of all class warfare. And all ideologies assume that there is not enough to go around, and this has been the rationalized working hypothesis of all the great sovereign claims to great areas of the earth.

Certainly, the corollary to Darwin's theory of evolution which expounded "survival only of the fittest," seemed to fit neatly with Malthus who observed that only a few were surviving their full span of years. It was assumed to be obvious by those in power that a scientific law supported and vindicated their position. That friend and relative of my father's who first introduced me to Malthusian thinking was a very rich man in an age when rich men were proportionally much fewer than today. And he said to me, "Young man, I think I must tell you some things that aren't going to make you very happy. I know that you are impressed with your grandmother's Golden Rule: 'Do unto others, as you would they should do unto you.' But a few of us now know from our closed system experts that the Golden Rule doesn't always work."

And he continued, "Those few of us who are rich and really have the figures know that it is worse than one chance in one hundred that you can survive your alloted days in any comfort. It is not you or the other fellow; it is you or one hundred others. And if you are going to survive and have a family of five and wish to prosper, you're going to have to do it at the expense of five hundred others. So - do it. And do it as neatly, cleanly and politely as you know how and as your conscience will allow. At any rate, that's what you are up against." He went on to say, "There are few even today who really know this is so. The others keep dying off, short of their potential years, but they keep themselves happy by having hope in infinite possibilities. So we won't tell them about it."

Quite clearly to the great pirates, it was a scientific fact that not only was there not enough to go around, but apparently not enough to go around for even one percent of humanity to live at a satisfactory sustaining standard of living. So survival - said the great pirates - was obviously a cruel and almost hopeless battle. They ran the world on the basis that these Malthusian-Darwin entropy concepts were absolute scientific laws since that was what their scientifically respected, intellectual specialists had told them. Even today, all political ideologies range somewhere between those of the great pirates or the Marxists. All of them assume an Armageddon or a final, in-the-end showdown between you or me.

And so we have then, men going about their business with guns instead of swords and we have even our grandfathers carrying revolvers against all the kinds of robbers of that time, and then saying, "Well, we can work together instead of all carrying our individual guns; we will observe some law and order, cooperating to the extent of being able to have big guns to take care of us jointly against the inevitable big showdown with some other country, some other group." Gradually, spurred on by ambitions for victory at war and its rich spoils, a few men began to make capital risks of time and resource investments in order to develop tools that promised in due course to make weapons superior to those which could be made by simpler means. These investments paid off. Since 1929, the great corporations have found that military research has given them all kinds of new opportunities to make money.

But the essence of all the great corporations is still, "How do we make a profit this year?" Every department head in every corporation has to be able to show a profit this year or he will not be that department head next year. He is therefore only interested in short term research applications which lead only to immediate gain for this year. The business man delegates long-

term planning to the politician. Then we find that the politician is really only concerned about winning his next election. Both politics and big business are inherently shortsighted: Both believe that they have left all the long-distance thinking to the military. The military has turned over the actual fulfillments of their programs to the scientists. We have then, the scientists undertaking some very extraordinary things which have been initiated by military patronage.

Anybody who has been in Washington is familiar with budgeting and with the modes of developing public recognition of problems and of bringing about official determination to do something about solutions. In the end the problems are rarely solved - not because we don't know how -- but because it is discovered either that it is said by those in authority that "it costs too much", or that when we do finally identify the fundamental factors of a problem, and laws are enacted to cope incisively with those factors, then there are no funds known to be available with which to implement the law. There comes a money bill a year later for implementation of that law, and, with it, the political criteria of assessing wealth by which the previous years' bill would now seemingly "cost too much." So compromise follows compromise. Frequently nothing but political promises or underbudgeted solutions result.

The original legislation partially stills the demands. The pressures on the politicians are lowered and the lack of implementation is expeditiously shrugged off because of seemingly more pressing, ergo higher priority, new demands for "the money." The most pressing of those is for war where the politicians suddenly accredit weaponry tasks costing many times their previously asserted concepts of "what we can afford."

As an example, in World War I, the "out" pirates operated behind their German-Austrian stooges and lost. As I mentioned earlier, they almost vanquished the "in" pirates through the introduction of submarine warfare. The shipping tonnage attrition of the submarine line of supply was horrendous. To offset it, the magnitude of industrial technology introduced and employed in World War I was without historical precedent. It soared out of the pocketbook range of the "in" pirates, who, of course, didn't say so. No one knew what they had, but their wealth had been thought to be fabulous beyond calculation. Their total world monetary bullion gold supply was in fact worth thirty billion 1914 U. S. A. dollars. By 1915, the "in" pirates had exhausted the thirty billions in armaments purchases, much of which was torpedoed to the bottom of the ocean. By 1916, they had purchased another forty billion dollars worth of armaments on credit, mostly from the United States. But they were losing ground on the battlefield. Their credit exhausted and threatened with the loss of their centuries long supremacy of the world, they finally induced the U. S. A. to come into the war on their side by persuading the U. S. A. people that the fate of democracy was at stake and that only the U. S. A. might save it.

On entering the war, the government of the United States commandeered all of its industries and all the national resources and speeded production to capacity. In addition they trained and transported an army of one million men over the Atlantic to the European front. By November 1918, the U. S. A. had produced and transported one hundred and seventy billions worth of armaments overseas to her own and her allies' armies. This production and manpower out-produced and out-fought the "out" pirates' sovereign forces.

Thus under lethal emergencies vast new magnitudes of "money" come mysteriously into effective operation. Although, we don't seem to be able to afford to do the logical things we say we ought to be doing to forestall warring -- that is, producing enough to satisfy all the world needs.

Under pressure we always find that we can afford to wage the wars brought about by the vital struggle of "have-nots" to share or take over the bounty of the "haves." Simply because it had seemed, theretofore, to cost too much to provide vital support of those have-nots.

The "haves" are thus forced by defense suddenly to articulate wealth capabilities many times the amounts they had known themselves to possess, and many times what it would have cost to give adequate economic support to the particular have-nots involved in the warring and, in fact, to all the world's have-nots.

The adequately macro-comprehensive and micro-incisive solutions to any and all vital problems never cost too much. As it is said "in the end," they always cost the least if paid for adequately at the outset of the vital problem's recognition. Being vital, the problems are evolutionary, ergo inexorably unavoidable. The constantly put-off or undermet costs and society's official bumbling of them, clearly prove that man does not know at present what wealth is nor how much of whatever it may be is progressively available to him.

We have not flushed out a major variable in our general systems problem. The question: "What is wealth?" commands our prior consideration.

The Wall Street Journal reported on the September-October, 1967 deliberations of the International Monetary Fund held at Rio De Janeiro, Brazil. Many years and millions of dollars were spent maneuvering for and assembling this monetary convention, the net result of which was the weak opinion that, "It would soon be time to consider doing something about money." The convention felt our international balance of payments and its gold demand system to be inadequate. They decided that the old pirate's gold was still irreplaceable, but that after a few years, they might have to introduce some new "gimmick" to augment gold as an international monetary base.

At present there is about seventy billion of mined gold known to exist onboard our Spaceship Earth. A little more than half of it, i.e. forty billion is in the "monetary" classification in the form of various national coinages or officially banked gold bullion bars. The rest is in private hordes, jewelry, gold teeth, etc.

Since income represents an average return of 5% on capital invested, we may assume from an estimate of the world's annual gross product that the capital assets, in the form of

industrial production on board our Spaceship Earth, are at present worth in excess of a quadrillion dollars. The world's total of seventy billion dollars in gold represents only three one-thousands of one percent of the value of the world's organized industrial production resources. The gold supply is so negligible as to make it pure voodoo to attempt to valve the world's economic evolution traffic through the gold-sized needle's "eye."

We must therefore proceed ever more earnestly with our general systems analysis of the problems of human survival -- on the premise that at present neither the world's political officials nor its bankers know what wealth really is.

First I am going to make a series of analytical statements to you, and if anyone in the audience disagrees with me on any statement, we will discard that statement. Only those of all my statements to you which remain 100% unprotested, will we rate as being acceptable to all of us.

First I say: "No matter what you think wealth may be and no matter how much you have of it, you cannot alter one iota of yesterday." -- No Hands!

Imagine now a man in a shipwreck. He's rated as a very rich man, worth over a billion dollars, by all of society's accredited conceptions of wealth. He has taken with him on his voyage all his stocks and bonds, all his property deeds, all his checkbooks and, to play it safe, he has even brought along a lot of diamonds and gold bullion. The ship burns and sinks and there are no life boats for they too have burned. If our billionaire holds on to his gold, he's going to sink a little faster than the others. So I would say he hadn't much left either of now or tomorrow in which to articulate his wealth and since wealth cannot work backwardly his kind of wealth is vitally powerless. Obviously his kind of wealth has no control over either yesterday, now, or tomorrow. He can't extend his life with that kind of wealth. Does anybody in this audience disagree with that statement? No hands! Well, we are eliminating many irrelevancies as we play the "Bits" game just as it is played by the ruthlessly realistic, utterly unsentimental, properly programmed, computer.

I now want to speculate about what I think we all really mean by wealth in these terms: "Wealth is our organized capability to cope effectively with the environment in sustaining our healthy regeneration and decreasing both the physical and metaphysical restrictions on the forward days of our lives."

Are there any dissenting hands? No hands!

Well, having first disposed of what wealth is not, we now have produced a generalized statement that roughly contains somewhere within it a precise definition of what wealth is.

Now we can account wealth more precisely as: The number of forward days for a specific number of people we are physically prepared to sustain at a physically stated time and space liberating level of metabolic and metaphysical regeneration.

Now we are getting sharper.

Inasmuch as we are now learning, on the one hand, more about our Spaceship Earth and its radiation supply ship, Sun, and, on the other, about its Moon, acting as the Earth's gravitationally pulsing "alternator," which together constitute the prime generator and regenerator of our life supporting system, I must observe also that we're not going to sustain life at all, except by our successful impoundment of more of the Sun's radiant energy aboard our spaceship. We could burn up the Spaceship Earth itself to provide energy, but that would give us very little future.

It is obvious that real wealth is a forwardly operative metabolic regenerating system. Quite clearly we have vast amounts of income wealth as Sun radiation and Moon gravity to implement our forward success. We have been living only on our energy savings by burning up the fossil fuels which took billions of years to impound from the Sun or else living on our capital by burning up our Earth's atoms which is lethally ignorant and utterly irresponsible to our coming generations and their forward days. Our children and their children are our future days.

Having identified the ignorance of society regarding its wealth capabilities to be a major factor in its frustration and having roughly identified the meaning of wealth and intending later to sharpen its identity, we will now tackle the next phase of humanity's total survival, prosperity, happiness and regenerative inspiration with the problem solving power of general systems theory as combined with both (A) computer strategy -- which is known as cybernetics and with (B) synergetics -- the latter consisting of the solving of problems by starting with known behaviors of whole systems plus the known behaviors of some of the systems' parts. This advantageous information makes possible the discovery of other parts of the system and their respective behaviors -- as for instance in geometry where the known sum -- 180 degrees -- of a triangle's angles, plus the known behavior of any two sides and their included angle enables the discovery of the precise values of the other three parts.

Synergetics discloses that wealth -- which represents our ability to deal successfully with our forward energetic regeneration and provide increased degrees of freedom of initiation and non-interfering actions -- breaks down cybernetically into two main parts: Physical energy and metaphysical know-how.

Physical energy in turn divides into two interchangeable phases: Associative and disassociative-- energy associative as matter and energy disassociative as radiation.

Stating first that the physical Universe is all energy and symbolizing energy by E, Einstein formulated his famous equation E-M (matter's mass explained in the terms of C^2 or the speed of an omni-directional surface wave's unfettered expansion in a vacuum.)

Energy as matter and energy as radiation as Einstein had generalized hypothetically, were explicity proven by fission to be interchangeable covarients.

Physicists also have discovered, experimentally, that energy can neither be exhausted nor originated. Energy is finite and infinitely conserved.

This experimentally proven realization of some prime facts of the physical universe, contradicts the expressed thoughts of cosmologists, cosmogonists and society's economists at the beginning of the twentieth century before the speed of light was measured.

I came to Harvard University at the beginning of the century -- just before World War I. At that time, it was the consensus of scholarly thinking that because the Universe itself was seemingly a system, it too must be subject to entropy. Entropy, as defined, is that phenomenon by which every local system was found experimentally to be continually losing energy -- ergo, the Universe itself was thought to be losing energy. This indicated that the Universe was "running down", and that after a time evolution would abandon its abnormal energetic behavior and all would return to Newton's norm of "at rest". This being so, it was also assumed that all those who expended energy were recklessly speeding the end of the Universe. This was the basis of yesterday's conservatism. All who expended energy in bringing about further evolutionary changes were to be abhorred.

All this was assumed to be true before the experiments at the beginning of the twentieth century which gave scientists knowledge of the speed of light and of radiation in general. Thus, we suddenly discoverd it took eight minutes for the light to get to us from the Sun, two and a half years from the next nearest star beyond the Sun and many years for it to reach us from other stars. We learned only two-thirds of a century ago that some stars we have been looking at haven't been there for thousands -- possibly millions of years.

Then Einstein, Planck and other leading scientists said, "We're going to have to reassess and redefine the physical Universe". They defined the physical Universe as "an aggregate of non-simultaneous and only partially overlapping transformation events". They then said, "We must discover what it is we see when we observe new life forming. It could be that when energy disassociates here, it also may always be reassociating somewhere else."

And that is what all subsequent experimentation proved. The scientists found that the energy redistributions always added to 100%. The scientists then formulated a new description of the physical Universe which they called the new "Law of conservation of energy", which said that "Experiments disclose that energy can neither be created nor lost." Energy is not only conserved but it is also finite. It is a closed system. The Universe is a mammoth perpetual motion process.

We then see that the part of our wealth which is physical energy is conserved. It cannot be exhausted -- cannot be spent, which means exhausted. We realize that the word "spending" is now scientifically meaningless and obsolete.

Now I would like to talk about another component of wealth. Long ago, a man went through the woods, as you may have done and as I certainly have, trying to find the shortest way in a given direction. He found trees fallen across his path. He climbed over those criss-crossed trees and suddenly found himself poised on a tree that was slowly teetering. It happened to be lying across another great tree with its other end lying under a third great fallen tree. As he teetered, he saw the third big tree lifting. It seemed impossible to him. He went over and tried using his own muscles to lift that great tree. He couldn't budge it. Then he climbed back atop the first smaller tree, this time purposefully teetering it and, surely enough, it again elevated the larger tree.

I'm sure that the first man who found such a tree, thought it was a magic tree and probably dragged it home with him and guarded it jealously until his wife told him that any stout tree would do. Thus was extracted the concept of the generalized principle of leverage out of all of man's earlier successive special case experiences with such accidental discoveries. Only as he learned to generalize fundamental principles of the physical universe did man learn to use his intellect effectively.

Once man learned that anv tree would serve as his lever, his intellectual advantages accelerated. Man freed from special case superstion by intellect has had his survival potentials multiplied millions fold. Having used levers for milleniums, man thought of taking a series of bucket ended levers and of inserting the non-bucket end of each lever perpendicularly into a shaft arranged one after another like spokes around a wheel. He mounted that shaft in bearings, put it under a waterfall and let gravity fill each bucket in turn and then pull each filled bucket toward the center of the Earth, thus progressively rotating all the levers and making the wheel and its shaft rotate with great power. Then man connected this revolving shaft by pullied belts to other pullies on other shafts which drove machines to do many metabolically regenerating tasks in a way unmatchable by man's muscle power alone.

Man thus began for the first time to really employ his intellect in the most important way. He discovered how to use energy as matter in the form of levers, shafts and gear trains, and how to use energy as radiation which could elevate vaporized water as atmosphere allowing it then to be pulled back toward the center of the Earth from the clouds in the form of water-molecules collected in droplets.

From this point on, man's really important function in universe was his intellection which taught him to intercept the energy patternings in local universe and to reorganize and redirect those flow patterns so that they would impinge on levers to do the work of taking care of his forward metabolic regeneration.

What we have demonstrated powerfully is, that every time man makes a new experiment he always learns more. He cannot learn less. He may learn that what he thought was true was not true. By the elimination of a false premise his basic capital wealth which is his given lifetime is disembarrassed of further preoccupation with considerations of how to employ a worthless time-consuming hypothesis. Freeing his time for its more effective investment is also to give man increased wealth.

We find experimentally, regarding the metaphysical phenomenon intellect (which we call know-

how) that everytime we employ and test our intellectual know-how by experimental rearrangement of physical energy interactions (either associated as mass or disassociated as radiation) we always learn more. Know-how can only increase.

Now we have carefully examined and experimented with the two basic constituents of wealth -- the physical and the metaphysical.

Sumtotally, we find that the physical constituent of wealth - energy - cannot decrease and that the metaphysical constituent - know-how - can only increase. This is to say that everytime we use our wealth it increases.

This is to say also that wealth like entropy can only increase. Whereas entropy is increasing disorder evoked by dispersion of energy, wealth is the increasingly orderly concentration of physical power by the metaphysical capability of man -- as informed by repeated experiences from which he distills the generalized principles operative in all the special case experiences. Wealth is the effective magnitude of our physically organized anti-entropy.

The difference between mind and brain is that brain deals only with memorized, subjective, special case experiences and objective experiments while mind extracts and employs the generalized principles and integrates their effective employment. Brain deals exclusively with the physical, and mind exclusively with the metaphysical.

Wealth is the product of the progressive mastery of matter by mind and is specifically accountable in forward man days of established metabolic regeneration advantages and of hours of his life released from formerly prescribed entropy preoccupying tasks for his elective investment in further anti-entropic effectiveness.

Because our wealth is continually multiplying and our economic accounting systems are unrealistically identifying wealth only as matter and are entering know-how on the books only as salary liabilities, all that we are discovering mutually here today regarding the true nature of wealth comes as a complete surprise to world society - to both communism and to capitalism alike.

All our accounting today is of non-synergetic and only entropic phenomenon, mortgages, e.g. mortgagization, meaning literally, toward death-age. Wealth as anti-entropy compounded with synergy is as yet entirely unaccounted for on the operating capability ledgers of world society. We give an intrinsic value to the material. To this we add the costs of manufacturing which include energy, labor, overhead and profit. We then start depreciating this figure assuming swift obsolence of the value of the product. With the exception of small royalties which are usually avoided, no value is given for the inventiveness nor for the synergistic value given by one product to another by virtue of their complementarity as team components whose team work produces results of enormous advantage as, for instance, the lowly metal parts of a pump do in bringing petroleum from non-use to use.

As a consequence of true wealth's unaccounted, inexorably synergistic multiplication of ever increasing numbers of humanity's ever increasing forward days, between 1900 and today (1968) we have gone from less than one percent of humanity being able to survive in any important kind of health and comfort to 44 percent of humanity surviving at a standard of living unexperienced or undreamed of by any kind in any century before this twentieth century.

This utterly unpredicted, synergistic success occurred within only two-thirds of a century despite continually decreasing metallic resources per each world person. It happened without being consciously and specifically attempted by any government or business. It happened also only as a consequence of man's being synergistically equipped to do progressively more with less.

As we have learned, Synergy is the only word in our language which identifies the meaning for which it stands. Since the word is unknown to the average public, it is not at all surprising that synergy has not been included in the economic accounting of our wealth transactions or in assessing our commonwealth capabilities.

The synergetic aspect of industry's doing ever more work with ever less investment of time and energy per each unit of performance of each and every function of the weapons carriers of the sea, air and outer space has never been formally accounted as a capital gain of land-suited society. But the scientific facts are that simple tools that make complex tools are synergetically augmented by progressively more effective and previously unpredicted alloying chemical elements. The whole history of world industrialization demonstrates constantly surprising new capabilities resulting from various synergetic interactions amongst both the family of 92 regenerative and the transuranium members of the uniquely behaving chemical elements family.

Complex environmental evolution is synergetically produced by the biologicals and their tools, as well as by the great inanimate physiological complex of events such as earthquakes and storms which have a constant challenging effect upon the individual biological inventiveness. Both the challenges and the cause are regenerative.

Our commonwealth is also multiplied in further degree by experimentally derived information which is both multiplying and interacting at an exponential rate. The synergetic effect upon the rate of growth of our commonwealth augmentation has been entirely overlooked throughout all the accounting systems of all the ideologically divergent political systems.

Our wealth is inherently commonwealth and our commonwealth can only increase, and it is increasing at a constantly self-accelerating synergistic rate.

However, we inadvertently dip into our real, unaccountedly fabulous wealth in a very meager way only when our political leaders become scared enough by the challenges of any enemy. Then only do we find that we have to afford whatever we need. The only limitation here is that our production engineers must be able to envision the production multiplying steps to be taken. This progressive envisioning depends both on the individual and on the experimentally proven, but as yet untapped state of the pertinent metaphysical arts, as well as upon the arts, as well as upon the range of

resources strategically available at the time and, in particular, upon the inventory of as yet unemployed but relevant alternate inventions.

In respect to physical resources, man has, until yesterday, assumed that he could produce his buildings, machinery and other products only out of the known materials. From time to time, in the past, scientists discovered new alloys which changed the production engineering prospects. But now in the aerospace technology man has developed his metaphysical capabilities to so advanced a degree that he is evolving utterly unique materials "on order". Those new materials satisfy the prespecified physical behavior characteristics which transcend those of any substance previously known to exist anywhere in the Universe. Thus, the re-entry nose cones of the man launched and rocketed satellites were developed. Synergy is of the essence.

It should be remembered, that throughout all pre-twentieth century history, wars were devastating to both winners and losers. Pre-industrial wars took the men from the fields, and the fields where the exclusively agricultural-wealth germinated, were devastated. Therefore, it came as a complete surprise that World War I, the first full-fledged industrial era war, ended with the United States in particular, but also in lesser degrees with Germany, England, France, Belgium, Italy, Japan and Russia all coming out of the war with much greater industrial production capabilities than those with which they had entered. That wealth was soon misguidedly invested in the second World War from which all the industrial countries emerged with even greater wealth producing capabilities, despite the superficial knockdown of the already obsolete building. It was irrefutably proven that the destruction of the buildings by bombing, shell fire and flames left the machinery almost unharmed. The productive tooling capabilities multiplied unchecked as did their value.

This unexpected increase in wealth by industrial world wars was caused by several facts but most prominently by the fact that in the tool-up of tools that make a complex of industrial tools, the number of tools that made the end product armaments and ammunition were negligible as compared to the redirectable productivity of the majority of the tools that constituted the synergistic tool complex. Secondly, the wars destroyed the obsolete structures whose factual availability, despite their obsolescence, had persuaded their owners to over extend their usefulness and exploitability. This had blocked the acquisition of up-to-date tools. Thirdly, there was the synergetic surprise of alternative of "substitute" technologies which were developed to bypass destroyed facilities. The latter often proved to be more efficient than the tools that were destroyed. Fourthly, the metals themselves not only were not destroyed, but were acceleratingly reinvested in new, vastly higher performance tools. It was then that the World War losers such as Germany and Japan became the post-war industrial winners.

It is only under the stresses of total social emergencies as thus far demonstrated by man that effectively adequate alternative technical strategies synergetically emerge.

The first census of population in the United States was taken in 1790. In 1810 the United States Treasury conducted the first economic census of the young democracy. There were at that time one million U. S. A. families. There were also one million human slaves. This did not mean that each U. S. A. family had a human slave, far from it. The slaves were owned by relatively few.

The Treasury ajudged the monetary value of the average American homestead, lands, buildings, furnishing and tools to be worth sumtotally $350.00 per family. The Treasury appraised the average worth of each slave as $400.00. It was estimated that the wilderness hinterlands of America were worth $1,500 per family. The foregoing assets plus the canals and toll roads brought the equity of each U. S. A. family to a total of $3,000. This made the national wealth of the U. S. A., as recognized by man, worth three billion dollars.

Let us assume that the united American citizens of 1810 - practicing supreme wisdom - had convened their most reliably esteemed and far-sighted leaders and had asked them to undertake a 150-year, grand economic and technical plan for most effectively and swiftly developing America's and the world's life support system; this system to be fully realized by 1960.

At that time, it must be remembered, the telegraph had not been invented. There were no electromagnetics nor mass-production steel. Railroads were as yet undreamed of, let alone wireless, X-ray, electric light, power by wire and electric motors. There was no conception of the periodic table of the atoms or of the electron.

Under those circumstances of an assumed capital wealth of the United American States, both public and private, amounting to only three billion dollars, it is preposterous to think of humanity's most brilliant and powerful leaders electing to invest their "all" of three billion dollars in a "thousand times more expensive" three trillion dollar undertaking. However, this has since transpired, but only under the war enforced threat of disintegration of the meager rights won thus far by common man from history-long-tyrannical powers of an often ignorant and cruel few.

In 1810, it was also unthinkable by even the most brilliant leaders of humanity that 170 years hence, in 1970, the gross national product of the U. S. A. would reach one trillion dollars per year. (This is to be compared with the meager forty billion of the world's total monetary gold supply). Assuming a ten percent earning interest, this 1970 U. S. A. trillion dollar product would mean that a capital base of ten trillion dollars was operative within the United States alone. (Remember that the 1810 national leaders had accredited only three billion dollars of national assets). The wisest humans recognized in 1810 only one-three-hundredth of one percent of the immediately thereafter "proven value" of the U. S. A.'s share of the world's wealth generating potentials. Of course those wisest men of the times would have seen little they could "afford" to do.

Our most reliable, visionary and well-informed great-grandfathers of 1810 could not have forseen that in that meager

century and one half of all the billionsfold greater reaches of known universal time, that the human life span would be trebled, that the yearly real income of the individual would be tenfolded, that the majority of diseases would be banished, and human freedom of realized travel one hundred folded; that humans would be able to whisper effortlessly in one another's ear from anywhere around the world apart and at a speed of 700,000,000 miles an hour with their audibility clearly reaching to the planet Venus, and that human vision from Earth would be increased to see local pebbles and grains of sand on the moon.

Now in 1968, 99.9 percent of the accelerating accelerations of the physical environment changes effecting all humanity's evolution are transpiring in the realms of the electromagnetic spectrum realities which are undetectable directly by the human senses. Because they are gestating invisibly it is approximately impossible for world society to comprehend that the changes in the next 35 years - ushering in the twenty-first century - will be far greater than in our just completed century and a half since the first U. S. economic census. We are engulfed in an invisible tidal wave which as it draws away will leave humanity, if it survives, cast up upon an island of universal success uncomprehending how it has all happened.

But we can scientifically assume that by the twenty-first century either humanity will not be aboard Spaceship Earth, or, if approximately our present numbers as yet remain aboard, that they then will have recognized and organized themselves to realize effectively the fact that humanity can afford to do anything it needs and wishes to do and that it cannot afford anything else.

As a consequence Earth-planet based humanity will be physically and economically successful and individually free in the most important sense. While all enjoy total Earth, no human will be interfering with another and none will be profiting at the expense of another. Humans will be free in the sense that 99.9 percent of their waking hours will be freely investible at their own discretion. They will be free in the sense that they will not struggle for survival on a "you" or "me" basis and will therefore be able to trust one another and be free to cooperate in spontaneous and logical ways.

It is also probable that during that one-thrid of a century of the curtain raising of the 21st Century that the number of booboo's, biased blunders, shortsighted misjudgments, opinionated self-deceits of humanity will total, at minimum, six hundred trillion errors.

Clearly man will have backed into his future as evolution, operating as inexorably as fertilized ovaries gestate in the womb, will have brought about his success in ways as synergetically unforeseeable to us today as were the three trillion dollar development of the last 150 years unforeseen by our wisest great-grandfathers of 1810.

I have so far introduced to you a whole new synergetic assessment of wealth and have asked that you make a show of hands whenever any of you detected fallacies in the progressively stated concepts of our common wealth.

Thus we have discovered together that we are unanimous in saying that we can afford to do anything we need or wish to do.

A year ago, I spoke to a general University audience of fourteen hundred people at Stanford University in Palo Alto, California. I was giving the curtain opener address in a series of lectures they are presenting to the whole university community called the Twenty First Century, a series which is to last for several years. I asked that audience to show hands if any objected to the same challenge to a number of equally large audiences of University or of leading professional congresses around the world and, as with yourselves, none objected -- in fact, all applauded.

It is utterly clear to me that the highest priority need of world society at the present moment is a realistic economic accounting system which will, for instance, rectify such nonsense as the fact that a top tool maker in India, the highest paid of all craftsmen, gets only as much per month for his work in India as he could earn per day for the same work if he were employed in Detroit, Michigan in the U. S. A. How can India develop a favorable trade balance under those circumstances?

If it can't have a workable let alone favorable balance, how can these half billions of people participate in world intercourse? It is estimated that 100 million Hindus have never heard of America.

As a consequence of the great pirates' robbing Indo-China for centuries and cashing in their booty in Europe, so abysmally impoverished, underfed and physically afflicted have India's and Ceylon's billions of humans been throughout so many centuries, that it is their religious belief that life on Earth is meant to be exclusively a hellish trial and the worse the conditions encountered by the individual, the quicker his entry into Heaven. For this reason, attempts to help India in any realistic way are looked upon by a vast number of India's population as an attempt to prevent their entry into Heaven. All this because they have had no other way to explain life's hopelessness. On the other hand, they are extremely capable thinkers, and free intercourse with the world could change their views and fate. It is paradoxical that India's population should starve as one beef cattle for every three people wander through India's streets, blocking traffic as sacred symbols of nonsense.

One of the myths of the moment suggest that wealth comes from individual bankers and capitalists. This concept is manifest in the myriad of charities that have to beg for alms for the poor, disabled and helpless young and old in general. These charities are a hold-over from the old pirate days when it was thought that there would never be enough to go around. They also are necessitated by our working assumption that we cannot afford to take care of all the helpless ones.

But at the present moment in history, we find ourselves in a fundamentally different economic position. When over a decade ago, Eisenhower went to

meet with Khruschev in Geneva, both had been informed by their military and scientific aids regarding the magnitude of the destructive capability of the atomic bomb. And as he went into that conference, Eisenhower said, "There is no alternative to peace." I'm sure that Khruschev, with the same realization, must have felt the powerful responsibility of that moment. Both being political realists and hard fact men, they knew that because of local political expedience they would not be able to make any important peace agreements conceived solely by themselves. Their proposals and agreements, if any, would have to be backed by their respective political parties, and their parties were always in mortal contest back at home. There, their chief opposition parties waited upon any altruistic move of the "ins" as opportunities to impeach them for treachery to their respective sovereign power's ideological premises. Any soft-headed step on the part of the leader would throw his party out. While Eisenhower and Khruschev could never yield an inch politically, ideologically or militarily, both of them brought along their atomic scientists and allowed them to talk to each other in a limited manner regarding any at all possible peaceful uses of the atom.

Only these few years ago, at this meeting in Geneva and its companion and coincidental in time meeting of the food and agricultural organization of the United Nations, it came clearly into scientific view - as reported unequivocably by Gerard Piel, publisher of the Scientific American - that for the first time in the history of man, it was in evidence that there could be enough of the fundamental metabolic and mechanical energy sustenance for everybody to survive at high standards of living - and, furthermore, there could be enough of everything to take care of the increasing world population while always improving the comprehensive standards of living. Granted proper integration of world around potentials by political unblockings, there can be enough to provide all man with an enjoyment of all Earth at a higher standard of living than all of yesterday's kings ever knew and without self-interferences or one man being advantaged at the expense of any other.

But clearly, both political leaders and their respective states were then and are still today frustrated by all the political checks and balances each side has set up to protect and advantage only their own and their allies side in view of yesterday's dictum that there was only enough of what it takes to support one in one hundred. So all the age-long fears, all the bad habits and short-sighted expedients that are stratified into custom and law are stopping what must be done to realize man's newly realized potential.

Just as all 91 of the 92 chemical elements thus far found aboard our spaceship are completely involved in the world around industrial network, the full family of chemical elements are unevenly distributed, and therefore our total planet must at all times be involved in the industrial integration of the unique physical behaviors of each of all the elements.

But paradoxically, at the present moment our Spaceship Earth is in the perilous condition of having the Russians sitting at one set of the co-pilots' flying controls while the Americans sit at the other; France controls the starboard engines and the Chines control the port engines while the United Nations controls the passenger operation. The result is an increasing number of U.F.O. hallucinations which reportedly are darting backwards and forwards and around in circles, getting nowhere, at an incredibly accelerating rate of speed.

The best the politicians can think up are ways of making the world work lopsidedly for the exclusive benefit of their particular elite party within their respective "sovereign" political entities. This calls for modernized armaments galore. This puts every mill and all their people to work. To muster the superficial political authority adequate to justify taking their side into battle against the other sovereign entities the dictatorial politicians have gone into the general business of inventing the utter undesirability of the political and cultural existence of their chosen adversary victims.

So, following the precedent of their old pirate masters, for the last half century the politicians have been telling the engineers and scientists what to do. And for the last half century, we, the people of the world, have gone through the nonsense of fearfully and lazily persuading ourselves that our respective local politicians and their ideologies could and would make the world work. Thus we have been persuaded to first hate and then later to unhate our successive politically evoked "enemies".

But the facts that confront us today make it clear that if we take away the energy distributing networks and any and all the industrial machinery from America, Russia, and all the world's industrialized countries and dump it in the ocean, within six months over 2 billion swiftly and painfully deteriorating people will starve to death. On the other hand, if we take away all the politicians, all their ideologies, their professional protagonists and their ultimate political authority weapons from all countries on Earth and send them off on a trip around the Sun - but leave humanity everywhere their present energy and communication networks, industrial machinery, routine production and distribution personnel then no more humans will starve nor be afflicted in health than at present.

As I said to you earlier, despite the constant increase in human population and constant decrease of metals per person, between 1900 and 1968 the number of people attaining economic and physical success by full participation in the highest standard of living progressively developed by world industrialization - a personal standard of living and health superior to that ever enjoyed by a pre-twentieth century monarch - rose steadily from less than 1% to 40% of all living humanity. The 40% of humanity thus surprisingly grown successful, despite constantly diminishing physical resources per capita, can be explained, therefore, only by the doing-more-with-less invention revolution.

The doing-more-with-less revolution does not accomplish this stepped-up efficiency as much by penny-pinching and progressive refinement of a given technique as by substitution of a whole new technology or a whole new industry or a com-

pletely new general systems change -- for instance, the shift from wire to wireless communication systems wherein one Telstar weighing only one-quarter of a ton out-performs, and in due course, displaces the trans-oceanic cables systems weighing hundreds of thousands of tons for handling the same number of messages in an inferior way.

The doing-more-with-less revolution has in turn been generated almost exclusively by the technology of the world's weaponry race whose ultimate objective has always been to deliver the greatest blows the furthest, most accurately and swiftly with the least effort.

The doing-more-with-less economic success of 40% of humanity, accomplished in only a half century, occurred as the ultimate, but inadvertent fall-out into the domestic economy of the weapons developed technological advances.

The doing-more-with-less effort cannot be attributed to any political doctrine. Political doctrine undertakes only to do more with more - more security with higher, thicker and heavier walls - more and bigger guns - more and more soldiers who only consume rather than produce and conserve wealth.

Fall-out of the ever-more-capability, with-ever-less expenditure-of-effort, time-and-material-per-each-unit of performance, came primarily, as we have seen, from the sea and then from the air and space weaponry support industries. Its fall-out into domestic commonwealth affairs has flourished equally well under all the opposing ideologies.

Fortunately, the do-more-with-less invention iniative does not derive from nor depend upon political debate, bureaucratic licensing or private economic patronage. The license comes only from the blue sky of the inventor's intellect. No one licensed the inventors of the airplane, telephone, electric light and radio to go to work. It took only five men to invent these world transforming do-vastly-more-with-exquisitely-less developments. Herein lies the potentially swift effectiveness of the world design revolution.

It is possible - and is going to be necessary - if society is to continue on Earth - for the professional scientists, engineers and architects to satisfactorily anticipate the economic needs of not only the next generation of humanity, but of all generations of all men to come. It is going to be necessary for the scientists, engineers, and professionals in general, and of the world students in particular, to take the initiative in respect to articulating a technological design revolution towards making the world work for all.

By these means, we shall see those advanced technologies developed for space air warfare directed out from weaponry into "livingry". For example, think that when we double the length of an airplane fuselage, we increase its surface area by four and increase its volume by eight. This means that every time we double the length of a ship, we eight-fold its useful cargo and passenger space while only four-folding its surface. The amount of surface of a ship governs its friction and drag. But, the larger the ship, the more economically its cargo can be carried. Yesterday's limitation in airplane size was occasioned by their horizontal speeds requiring longer and longer landing strips. But the new generation of large airplanes now emerging that will carry from 700 to 1,000 passengers and more, are all equipped for vertical take off and landing. This completely does away with the need for prepared landing strips. With the long landing strip limitation removed the size of the new airplanes will increase very rapidly.

To take advantage of the progressive economy gains of increasing size, leading airplane manufacturers already have airplanes on their engineering design boards of a size adequate to carry ten thousand passengers or their equivalent in cargo. The ten thousand passenger ship has a length equivalent to that of the Empire State Building. We shall be able to produce Empire State Building size skyscrapers in horizontal position under factory controlled conditions in mass production jigs with mass production tools.

Working on scaffolds, the Empire State Building was erected under approximately non-controlled conditions of wind, rain, heat and cold in the heart of New York City's traffic. One man was killed for every floor of the Empire State Building's 84 stories. No men should be killed in the production of the horizontal skyscraper in the airplane factory. Such skyscraper size airplanes may then be taken from their factory and with vertical take-offs and temporarily applied wings flown horizontally with minimum effort to any position around the world. Although they could be landed horizontally, their vertical take-off equipment could there be used to up-end them. They could then be anchored and braced and serve as skyscrapers. Thus we see that whole cities can be flown to any location around the world and also removed in one day to another part of the world just as fleets of ships come into port and anchor in one day and then are off for other parts of the world. These are the kinds of technologies that will come to service humanity as man's highest capabilities are directed towards a "livingry" art.

We have learned that only and exclusively through the use of his mind can man further inventively employ those generalized principles operative in universe to conserve the locally available physical energy of the only universally unlimited supply. Only thus can man put to orderly advantage the various, local and otherwise, disorderly behaviors of the entropic, physical universe. Man can and may metaphysically comprehend, anticipate, shunt, and meteringly introduce the evolutionarily organized environment events in the magnitudes and frequencies that best synchronize with the patterns of his successful and metaphysical metabolic regeneration while ever increasing the degrees of humanity's space and time freedoms from yesterday's ignorance-imposed, survival-processes-sustaining tasks.

We must comprehend not only that physical energy is conserved, but also that it is ever increasingly deposited as a fossil-fuel savings account aboard our Spaceship Earth through photosynthesis and progressive, complex, topsoil fossilization buried ever deeper within Earth's crust by frost, wind, flood, volcanoes and earthquake upheavals.

We have thus discovered also that we can make all of humanity successful through science's world engulfing industrial evolution provided that: we are not so foolish as to continue to exhaust in a split second of astronomical history the orderly energy savings aboard our Spaceship Earth. These energy savings have taken vast millions of years to put into our Spaceship Earth's life - regeneration-guaranteeing bank account for use only in self-starter functions.

The fossil fuel deposits are to Spaceship Earth as our storage battery is to our automobile's self-starter and the main engine and its main fuel tank. The fossil fuel savings account has been put aboard Spaceship Earth for the exclusive function of getting the new machinery built with which to support life and humanity at ever more effective standards of vital physical energy and reinspiring metaphysical sustenance while living exclusively on our Sun radiation's and Moon pull gravity's tidal, wind and rainfall generated pulsating and therefore harnessable energies daily "income" to operate our main industrial engines and their automated productions. As an example of Earth's "income" energy potentials, I point out to you that the available energy in three minutes of an average summer thunderstorm surpasses the potential energy of all the nations' atomic stockpiles.

Only by understanding this scheme may we continue for all time ahead to enjoy and explore universe as we progressively harness ever more of the celestially generated tidal and storm generated wind, water and electrical power concentrations. We cannot expend our fossil fuels any faster than we are "recharging our battery" which is more precisely the rate at which the fossil fuels are being continually deposited within the Earth's crust. The too-shortsighted and debilitating exploitation of fossil fuels and atomic energy are similar to running our automobiles only on self-starters and batteries and as the latter become exhausted, replenishing the batteries only by starting the chain reaction consumption of the atoms with which our automobiles are constructed.

We have discovered that it is highly feasible for all the human passengers aboard Spaceship Earth to enjoy the whole ship without any individual's interfering with another and without any individual being advantaged at the expense of another, provided that we are not so foolish as to burn up our ship and its operating chemical-exchange equipment. Typical of the subsidiary problems within the whole human survival problem the ramifications of which now go beyond solutions historically found without general systems theory, is the problem of pollution. And in speaking of pollution, I mean not only of our air and water, but also of the information stored in our brains.

In respect to the air we find: Yes, we do have ways of precipitating the fumes, but after this we say, "It costs too much." There are also ways of desalinating sea water, but we say, "It costs too much." These too narrow treatments of these problems never face the inexorably evolving and solution insistent problem of "what it will cost" when we don't have sun's vital energies reaching the planet in amounts necessary to sustain Earth's chemical exchange regenerative process after a too high pollution reflectivity of the atmosphere. "What will it cost" when we don't have air to breathe or the water with which to survive?

We cannot survive without water for the length of time it takes to produce and install the desalinization equipment adequate to supply only New York City. A sustained and often threatened water shortage in New York City would mean death for millions of humans. Each time the threat passes, the old statement "it costs too much" again blocks realization of our desalinization capability.

That man is endowed with such intuitive and intellectual capabilities which allow him the range to discover both a real wealth accounting system to answer the absurdity of "it costs too much" questioning as well as discovering the R.N.A./D.N.A. genetic code plus those other generalized principles governing the fundamental design controls of life systems, nuclear energy and chemical structuring is part of the extraordinary anticipatory design of the Spaceship Earth, its equipment, passengers and internal support systems. It is therefore paradoxical but, as we shall see, strategically explicable, that up to now, we have been mis-using, abusing and polluting this extraordinary energy exchanging system for successfully regenerating all life aboard our planetary spaceship.

One of the interesting things to me about our spaceship is that it is a mechanical vehicle just as is an automobile. The owner of an automobile must realize the necessity to useful operation of putting gas and oil into his vehicle, water into the radiator and generally taking care of the car as a whole. The machine must be kept in good order or it will fail to function. We have not been seeing our Spaceship Earth as an integrally designed machine which to be persistently successful must be comprehended and serviced in total.

Now there is one outstanding important fact regarding Spaceship Earth and that is that no instruction book came with it. I think it very significant that there is no instruction book for successfully operating our ship. In view of the infinite attention to all other details displayed by our ship, it must be taken as deliberate and purposeful that an instruction book was omitted. Lack of instruction forced man to find that there are two kinds of berries - red berries that would kill him and other red berries that would nourish him. And he had to find out ways of telling which was which berry before he ate it or die. So mankind was forced because of the lack of an instruction book, to use and develop intellect. Intellect is our supreme faculty enabling us to devise scientific experimental procedures and to effectively interpret the significance of the experimental findings. Thus, because the instruction manual was missing, we are learning how we can safely anticipate the consequences of an increasing number of alternative ways of extending our satisfactory survival and growth - both physical and metaphysical.

Quite clearly, all of life as designed and born is utterly helpless at the moment of birth. The human child stays helpless longer than does the young of any other species. Just as is

the anticipatory design of the mother's breast to feed her child, it is apparently part of the invention "man" that he is meant to be utterly helpless through certain anthropological phases and then begins to get on a little better. He begins to slowly discover some of the physical leverage multiplying principles inherent in universe as well as the many non-obvious resources around him which will further compound and multiply his knowledge regenerating and life fostering advantages.

I would say that designed into this Spaceship Earth's total wealth was a big safety factor which allowed man to be very ignorant for a long time until he amassed enough experiences from which to extract progressively the system of generalized principles governing the increases of energy managing advantages over environment.

The designed omission of the instruction book on how to operate and maintain Spaceship Earth and its complex life supporting and regenerating systems has forced man to discover retrospectively just what his most important forward capabilities are. His intellect had to discover itself. Intellect in turn had to compound the facts of his experience. Comprehensive reviews of the compounded facts of experiences by intellect brought forth awareness of the generalized principles underlying all special and only superficially sensed experiences. Objective employment of these generalized principles through general systems theory and comprehensive anticipatory design science to rearrange the physical resources of the environment will lead to humanity's eventual total success on Earth and its following readiness to cope with the far vaster problems of universe.

QUESTION PERIOD

FROM THE FLOOR: I wonder in this system that you have been predicting, if you would comment on the possibilities of machines beginning to learn and beginning to learn to learn so that a progression of machine learning capability is established. Would you accept this possibility, the implications it would have on societies in terms of taking over a great number of capabilities that today are accomplished by human energies and the implications this could have on things such as the distribution of wealth, leisure time, politics and any number of concepts that we now have?

DR. FULLER: You ask me a very big question: so big that I don't think that I shall have time for any other. (Laughter) The question concerned machine learning and learning to learn and its effects. And the effect it would have on economics, on employment and on the other various things humanity may undertake to do, whatever they may be. Let me begin what will be a very long answer by saying that there are now in the world several thousand powerful high-capacity, information-storage, electronic computers. The number of them approximately doubles yearly. That means a quarter-million of them by 1970, 250 million by 1980, and 8 billion by 1985 - more than two per each world human. The computers, both large and small, are machines for mathematical pattern cognition and recognition storage, retrieval, and coordination; the human brain is the prototype. As with the human brain, all pattern processing consists of two main classes: differentiation and integration; i.e., specialization and generalization. Differentiation identifies, evaluates, selects and separates the uniquely developing patterns. Integration ratiocinates comprehensively the coordination rates and magnitudes of complex interactions, developments or transformations.

To appreciate our state-of-computer-affairs, we first must be aware that throughout the last fifteen years many philosophers have been disturbed by the claims of some cyberneticians that computers are soon to displace the human intellect. If, instead, they had confined their prediction to the effectiveness of the human brain in respect to the computer, some of their claims might in time prove valid. For a long time philosophers assumed that the computer could not ask original questions. They said that the computer can only re-ask a question man has taught it to ask.

Despite the philosophers' wishful predictions, the computer has now demonstrated its ability to ask an original question - and it did so without being instructed. Otherwise the question could not be assessed as "original." The surprise demonstration came about approximately as follows: You can teach a computer to play games, for instance, to play checkers. You can also teach a computer to play backgammon. You also can build a computer with enough parts to permit it to play both backgammon and checkers at the same time.

Now, both backgammon and checkers are played at different rates. Furthermore, the checker moves are simple and direct. Backgammon is complex. Therefore the same computer, playing both games concurrently, completes the checker, moves far more rapidly than the backgammon moves. The backgammon rate is not an even wave-length multiple of the checker rate. Therefore, as with disynchronous, high-frequency twin motors, there develops a secondary low-frequency intermittent recurrence of coincident cycles, or interferences. Suddenly the machine has to make both the checkers and backgammon moves at the same time. Because the computer has a given wave length interval within which to make moves, and because the latter is too short to accommodate both moves, the machine has to decide which it will play first. It has to ask itself and then decide, "Which is more important, checkers or backgammon?" If the machine has stored enough information on variable factors, including previous decision, it may soliloquize: "Poor people play checkers and rich people play backgammon. I'd better cast my vote for the priority of backgammon because my memory storage also tells me that all the poor people are becoming rich and will emulate their conditioned-reflex image of being rich." From this moment, rightly or wrongly, the machine's storage contains this prospero-proletarian predilection.

"Which is more important, checkers or backgammon?" is an original question that had never been asked by man of himself or of the machine. We find that the asking of original questions is a consequence of interferences, whether in the computer or the human brain.

As far as the computer's differentiating function as judged by experts is concerned, it can be said that the computer is about to make man obsolete as a specialist because the machine can differentiate and seek out much more accurately, swiftly, and persistently than man can. The computer can stay up all night, night after night, selecting the greens from the blues under humanly intolerable conditions of heat, cold, smells, etc., yet never tire. That the machine is to replace man as a specialist, either in craft, muscle, or brain work, is an epochal event. The computer as superspecialist produces, multiplies, and administers "automation." Because the computer is superior to man as specialist, comprehensive world automation has always been developing inexorably and is now inexorably imminent.

The scientist-philosophers of computer integration say that because the asking of original questions is a consequence of interferences, and because interferences are products of time sequences, it follows that original questions are both functions and products of time. There must be a great number of moves and a vast number of computer components before enough time can elapse to develop new types of secondary or tertiary interferences that in turn may from time to time provoke original questions. The human brain as a computer mechanism consists of approximately a quadrillion times a quadrillion atoms in coordinate interpatterning. It will be a very long time before man will be able to develop an extracorporeal computer with that many transistors, storage cells, and other components. The experts also point out that, dealing in integrative complexity as a function of time, the human brain has always been dealing in complexity and has also been integrating comprehensive, historical continuity of human-experience-reflexed, design evolution relayed by human genes. Therefore, the experts say, we would have to have man-made computers running for 1,000,000 years or so in order for them to develop an equivalently integrated complexity. The experts do not see any immediate, or even far distant, competition by the machine computer with the human brain in the functions of complex integration.

We can have an integrator calculating, designing, and automatically manufacturing and putting together a geodesic dome in a giant jig, after which an automated "sky tug" helicopter will carry the dome away to install it and prepare it for human occupancy, thus providing a telephone-system type of inventing, developing, installing, maintaining, relocating, and continually self-improving service industry, able to provide telephone-ordered "instant housing." Such a computer-controlled housing and livingry service industry is even now feasible at 1 percent of the weight, time, and energy involvement per unit of volume and living equipment found in conventional high-standard suburbia or Park Avenue skyscraper technology.

In relation to the computer-tool hook-ups of automation, it is to be noted that all tools are externalizations of originally integral functions of human organisms. But externalized functions such as that of the cupped hand to hold water are capable, when translated into ceramic cups, of holding hotter or more acid liquids than the human hand could. This is to say that the limits of capability of the externalized functioning are extended but are not unique in principle. Whereas the craft tools developed by man operated independently, the industrial tools develop interdependently. The machine lathe requires the blast furnace and vice versa. Individual craft tools are the externalized counterpart of the individual's separate functions, while industrial tools are the organic externalization of man's integral metabolic regeneration.

The whole process of human life from conception through gestation to birth is entirely automated. After birth, despite parental ignorance of the process, the child grows from seven to seventy pounds and then as a youth often goes to one hundred and seventy pounds. Biological growth is entirely automated. Just as none of you are consciously routing the fish and potato you ate for dinner into the endrocine or some other gland to make hair or skin at this moment, we must realize that for at least 2,000,000 years, men have been reproducing and multiplying on a little automated spaceship called Earth, in an automated universe in which the entire process is so successfully predesigned that men did not even know that they were automated, regenerative passengers on a spaceship, and were so naive as to think they had invented their own success as they lived egocentrically on a seemingly static Earth.

Both the universal and the local ecological automation is so successfully designed as to allow man the luxury of thinking and acting "consciously" in meager and often perverse degree and even of meddling with the evolutionary mechanism without putting the mechanism's many degrees of freedom of action into jeopardy.

With our human-computer brains, we will not now consciously relate the mechanical computer's significances with other important information.

At the American Association for the Advancement of Science's annual 1961-62 meeting, among the thousands of papers presented, there were two of special interest to us. One dealt with all the biological species that have become extinct, the other with human tribes that have become extinct. These independent papers searched for common characteristics that might account for the extinction. In both cases it became clear that all the biological species that have become extinct and all the human tribes that have become extinct became extinct for one reason - over-specialization. Evolution involves constant change. When living species become so specialized that they cannot adapt to an unexpectedly large jump in evolutionary events they are "out."

Now, men in our industrial and educational system have become more and more specialized. Everyone, wanting economic security, has seemed to think that as a specialist he could command the toll gate of an expressway to unique and essential information. He thought: "A great many people will have to go through my specialization toll gate and I'll have a special, education-guaranteed economic security."

When we combine (a) the trend toward increasing specialization with (b) our knowledge that overspecialization leads to extinction, we realize that our unwitting human trend toward extinction was about to be realized as we developed the ability, through hyperspecialization in mathematical physics, to take the atom apart and thereafter to develop fission and fusion. The scientists, as specialization's victims, knew nothing of how to control the military, commercial, or political evolution of their discoveries. But just as we are about to blow ourselves up, we discover that nature has invented man with a built-in safety factor, an automated self-destruction-arrester. The safety factor is the built-in propensity not only to invent constructive tools that render the destructive inventions obsolete. In this case, the computer was immediately adopted by the military specialist to control the performance of rocket weapons. Here comes the surprise: The computer is now making man to some degree obsolete as a specialist. Therefore, since it was overspecialization that was leading us toward self-extinction, man has inadvertently invented his own anti-self-extinction device. First diverting man from becoming extinct through overspecialization, the computer and its automation will go on to produce enough metabolic capability to provide lavishly for all humanity. It will thus help to eliminate the you-or-I-must-die corollary, or the Malthus-Darwin theorem of survival only-of-the-fittest.

Displaced as a specialist, man is now being forced to become pre-occupied exclusively with integrative patterning considerations. This means an epochal reorientation. All the educational systems from now on must forsake specialization and cultivate powerful generalization. Everybody will be taught to be comprehensivists. Fortunately, that will come naturally because man is born to be comprehensive. It is his most unique biological characteristic. As he cross-breeds he becomes more comprehensively adaptive. Only inbreeding brings specialized capability. The greater the degree of freedom and acceleration, the higher the probability of cross-fertilization.

Architects constitute the last species of professional comprehensivists, for they try to put things together while the vast majority, the specialists, have been concentrating on taking things apart. The trend of world students will henceforth be toward becoming architects - that is, comprehensive and cooperative design-science artists.

A brand-new type of university will probably be required. The conditioned-reflex disease of "categoryitis" with which world society and its bureaucracy are chronically infected is going to have to be changed. Already when Alfred North Whitehead came to Harvard University early in his twentieth century from the great universities of England, he said that one of the things that was very noticeable at Harvard was that this great private school was initiating a new kind of pattern. It was beginning to build and staff the great graduate schools. The graduate schools dealt in specializations. In England the special preoccupations could be taken up within the general university. There were no special schools. Whitehead said that the American populus applauded the high specialization, and Whitehead saw that this pattern was being followed by the other leading private schools, colleges, and universities. Of course, the public schools and public universities immediately followed suit, taking on the graduate school patterns, because the political representatives of the public saw that their constituents would want the state school to incorporate these educational advances of the rich man's private schools. So specialization in graduate schools also became the "thing."

Whitehead said this meant that we deliberately sorted out the students, sieved them, picked the bright ones, and persuaded the brights to stay in the university and to go on to the graduate school. This meant that we began to make specialists out of our bright ones. The bright ones within their onw special category of their special school went on to develop further special nuances within their special areas. This all worked toward expertism and hybridism in the educational pursuits. It meant that the bright ones would learn much about their special subject. The public thought this to be desirable, because people like the idea of an "all-star" team. They thought that if we took groups of all-stars and put them together our commonwealth would surely prosper.

Whitehead said, "So far so good, and everybody is applauding." But he then said that the educational hybridism would mean that these men who were of high intellectual capabilities would have very high intellectual integrity. As men of high intellectual integrity they would quickly discover that they were making great progress in highly specialized areas of inquiry, and thus also they would know how little any other man outside of their own field could possibly understand of what was going on inside their own and inside any one field other than their respective specializations. Therefore, no specialist of integrity would think of going into some other expert's field and making quick assumptions as to the significance of that unfamiliar work. This would be considered preposterous. There would thus develop an increasing tendency to break down generalized communications and comprehensive prospecting between these experts. Certainly, they would not tend to join together and say: "I see I am developing this and you are developing that; if we associated them thus and so, such and such would be the economic consequences; therefore, let us do so by employing our credit as scientists with the banks in order to fund our undertakings." These men, Whitehead said, would do just the opposite and would become more and more subjective, growing into purer and purer scientists, to whom no banker would think of lending money on the basis of intellectual integrity alone. The scientists went in just the opposite direction of applied science. The more expert they were the less they would think of searching into the concept of how society might enjoy the fruits of their discoveries.

Whitehead pointed out that this system tended to break down the communication between the men of high intellectual capability in all special fields. Inasmuch as society wanted exploitation of the gains of their "all-star" teams, it meant that someone other than the prime intellects had to integrate and exploit their capabilities and their findings.

Than Whitehead said - which came as quite a surprise - inasmuch as we have deliberately sorted out the bright ones from the dull ones, we have inadvertently created a class of dull ones. Just as in mining, we have a big pile of tailings, and no one thinks much about tailings because they are interested only in the high-grade, quick-cash ore and the net metal that is taken out of the latter. He said that inasmuch as the "bright ones" are not going to be able to realize, integrate, and exploit their own potentials, we will have to leave it to the not-so-brights to put things together. This is what I have termed "Whitehead's dilemma."

At Harvard just before World War I, the dilemma Whitehead was talking about was developing in a very interesting way. What Whitehead didn't ask was how Harvard could afford those graduate schools. The fact is that neither Harvard nor any other university has ever operated at a profit. Certainly, schools, colleges, and universities don't have surplus earnings accruing which they can reinvest. Establishing graduate schools wasn't something private colleges could do on their own. The explanation is that the graduate schools were given to Harvard and the other leading private universities.

The next interesting question is, who gave them the graduate specialty schools? Well, the people who gave Harvard the schools were primarily the partners of J. P. Morgan and Company, or they were men who were founders or presidents of companies whose boards were run by J. P. Morgan. J. P. Morgan or his partners were at that time on the boards of nearly every important, powerful company in America. Morgan or his associates were also partners in the great unseen syndicate of world commerce mastery up to World War I.

And, as I said earlier, if you were an invisible world master of the water-ocean earth, you had to maintain the capability to create and run the top world navies - you had to have physical control of the biggest patterns. No matter what else we may say of these men today, they were magnificently imaginative big-scale operators. They had taken all that science had learned about energy and put it into their navies, faster, further, more accurately hitting power in order to keep in supreme command of physical affairs of mankind. Now, if you were world master, you would not be at all worried about being displaced by a dull one. You would only be apprehensive of and on guard against the bright ones. There is the old strategy of "divide and conquer." Anticipatory "divide and conquer" is more powerful than tardy "divide and conquer."

The old masters, then, in order to prevent themselves from being displaced from their great ocean mastery deliberately went to work taking the young, bright ones as they came along, and divided them up anticipatorily into non-self-integratable specializations, which made them completely innocuous as challengers to comprehensive grand strategy thinking and practical affairs integration. The bright ones thus became subject to integration of their high potential only at the masters' command. That was the key to the world pattern mastery up to World War I when general literacy of the rising world democracies posed threats to the old masters' all but impregnable sinecure.

World War I marked the end of the old masters. The old masters had set up local rulers of their own choosing all around the world in the various nations. They invented the political nations. They invented the geographical names - Greece, Italy - their nations were welded out of many tribes and battles. The masters said to their head-men stooges: "You command and hold the port here. You are the strong man locally, and I will make you head man. You can stay head man because I have the line of supply of maximum hitting power and maximum energy duration. If anybody challenges you, you get the supplies and he doesn't, for I control the oceans which carry the supplies. Therefore, you are going to be able to win." This was the old and great pattern of world mastery. The local politician was a man (a king, or whatever) put into a position of strength by the great masters who themselves remained scrupulously invisible. They preferred to remain invisible. The more invisible they were the longer they could stay master. No challenges would arise, because there was nothing visible to challenge. Secrecy was one of the greatest of the tools of the old masters. The visible head man on the beach - the local head man - was strong, however, simply by virtue of the old invisible master.

The old masters went out with World War I, but the customs and institutions inaugurated by them remain with us. And their one time henchmen, the bankers and the politicians, still counsel us that we can't afford the warring and the great society too. And because of the mythical concept that the wealth which is disbursed is coming from some magically secret private source no free and healthy individual wants that "hand out" from the other man whoever he may be. Nor does the individual wish to be on the publicly degrading "dole" line.

After World War II several million of our well trained healthiest young people came suddenly out of the military service. Because we had automated during the war to a very considerable degree to meet the "war challenges" there were but few jobs to offer them. In that emergency we legislated the GI Bill and sent them all to schools, colleges and universities. This act was interpreted as a humanly dignified fellowship reward and not as a "hand out." It produced billions of dollars of new wealth through the increased know-how and intelligence thus released which synergetically augmented the spontaneous initiative of that younger generation. This "reckless spending" of wealth we didn't know we had produced a synergetic condition that opened the greatest prosperity humanity has ever known, thus, exceeding even its most hopeful dreams.

But as we study mass production we also see that we cannot have mass production unless we have mass consumption. This was effected evolutionarily by the great social struggles of labor to increase wages and spread the benefits and prevent the reduction of the numbers of workers employed. The labor movement made possible mass purchasing, ergo mass production, ergo the availability of low prices on vastly improved products and services and services which have altogether established entirely new and higher standards of humanity's living.

Our labor world and all salaried workers including school teachers and college professors are now at least sub-consciously if not consciously afraid that automation will take away their jobs. They are afraid they won't be able to do what is called "earning a living" which is short for earning the right to live. This term implies that normally we are supposed to die prematurely and that it is abnormal to be able to earn a living. It is paradoxical that only the abnormal or exceptional are entitled to prosper. It even implied yesterday that success was so very abnormal that only divinely ordained kings and nobles were "entitled" to eat fairly regularly.

It is easy to demonstrate to those who will take the time and the trouble to unbias their thoughts that automation can swiftly multiply the physical energy part of wealth much more rapidly and profusely than can man's muscle and brain-reflexed manually controlled production. On the other hand humans alone can foresee, integrate and anticipate the new tasks to be done by the progressively automated wealth-producing machinery.

To take advantage of the fabulous magnitudes of real wealth waiting to be employed intelligently by humans and unblock automation's postponement by organized labor we must give each human who is or becomes unemployed a life fellowship in Research and Development.

This fellowship will permit them to comprehensively expand and accelerate scientific exploration and experimental prototype development. For every 100,000 employed in R. + D., one probably will make a breakthrough that will more than pay for the other 99,999 fellowships. Thus, production will no longer be impeded by humans trying to do what the machines can do better. Contrariwise, omniautomated and inanimately powered production will cultivate humanity's unique capability - i.e., its metaphysical capability. Historically speaking, that will happen within the next decade - there's no doubt about it, - but not without much social crisis and consequent educational experience regarding our unlimited wealth.

Through the universal R. and D. fellowships, we're going to start emancipating humanity from being muscle and reflex machines. We're going to give everybody a chance to develop their most powerful mental and intuitive faculties. Many who have been frustrated during their younger years - given their R. and D. fellowship - may feel like going fishing. Fishing provides an excellent opportunity to think clearly; to review one's life; to recall one's earlier frustrated and abandoned longings and curiosities. What we want everybody to do is to <u>think</u> clearly.

We soon will begin to generate wealth so rapidly that we can do very great things. I would like you to think what this may do realistically for living without spoiling the landscape or the antiquities or the trails of humanity throughout the ages, or despoiling the integrity of romance, vision, and harmonic creativity. The computers will soon eliminate war as an evolutionary function by providing enough wealth to supply all mankind. To give man adequate "purchasing power" to keep world industrialization in accelerated regeneration, we will pay all of humanity to go to the schools, to the universities and to the advanced studies laboratories where they will generate progressively higher standards of living from fewer invested resources.

THE SYSTEMS APPROACH AS APPLIED TO LARGE ARCHITECTURAL SYSTEMS

JOHN P. NASH

John P. Nash is Vice President and Assistant General Manager of the Research and Development Division of Lockheed Missiles & Space Company. In his experience at Lockheed he directed research and development activities in electronics, mathematics, and information processing in Communications and Control Research. As Manager of the Information Processing Division, he directed efforts of Mathematics and Computer Services, Logical Design, and Equipment Development organizations in carrying out an integrated program of computer development and utilization.

Prior to coming to Lockheed, Nash worked as a research physicist with Kimberly-Clark Corporation, initiating research in the development of radar systems at the Massachusetts Institute of Technology; and at the University of Illinois where he was Associate Professor, he directed the design of control circuits of ORDVAC and ILLIAC computers.

MR. NASH: Mr. Chairman, ladies and gentlemen. I can assure you that I am very happy to be with you here tonight, and for more than one reason. In the first place, I have been an admirer of modern architecture ever since John Eberhard (who will be your next speaker on this program in four weeks) and I were building our first homes at the same time at the University of Illinois seventeen years ago. Secondly, I have been an admirer of Boston ever since I lived here twenty-five years ago. A year ago, I renewed that friendship when I spent a tour at the Harvard Business School where my company sent me to get sharpened up in the ways of the business world, and today I have been wandering around town most of the day getting ever better reacquainted with my favorite old city.

Your new city hall probably caused a certain amount of comment when it was first proposed, and I am sure that the renewal near the library didn't receive an entirely unanimous and enthusiastic set of loud cheers from everybody. But I do like new things -- I do like contemporary architecture and contemporary design, so I do like the things that have been done -- even to my favorite old city.

Architecture, like every other technical discipline, is changing rapidly as it is influenced by the new technologies and the new ways of applying knowledge to complex problems. One development that is receiving increasing attention is "Systems Analysis" or "Systems Evaluation" or the "Systems Approach", which is our subject for tonight.

What do we mean by the Systems Approach? I am sure that most of you have a pretty good idea of what it is, but just to be sure that you understand, let me talk about it for a few minutes. It really amounts to analyzing a problem to determine just what it is we want to do and then to organize all of the factors that are involved in the solution of the problem. If there are alternative ways of doing things, each of them must be evaluated and compared with the others on the basis of cost, schedule, performance or whatever other criteria are significant. In the case of a building, we might decide to sacrifice certain costs for esthetic factors. But we would do so only after having done the best job possible in our "tradeoff studies", which is technical jargon for the detailed comparisons which must be made. These are the alternate designs that architects prepare.

The systems approach is used by every individual who organizes his thinking with respect to a job that he has to do. But as the job becomes increasingly complicated, the problem of evaluating all of the alternative decisions that are potentially possible becomes very complex indeed, and it is not possible without a carefully systematized approach, which on our big weapon systems requires large and sophisticated computer evaluations.

Such evaluations require that we have the approach quantified - that we have as much hard data as possible about the problem. Then it is possible to vary the parameters and arrive at alternate solutions.

How many of you have accompanied a client to a bid opening, only to find that the costs are 15% higher than the client can afford? Wouldn't it be nice to be able to say to a computer "cut it 15%" and have half a dozen alternatives to consider?

It was in weapon systems that the Department of Defense and its industrial contractors first developed and then honed to a fine edge the systems approach. As an example, consider the problems faced in the Polaris Weapons System -- a rocket to be launched from a submerged submarine at a target some 2,000 miles away.

There was no existing rocket and there was no existing submarine that could do the job. The questions that had to be answered were in the millions -- all the way from what shape should the missile have to work underwater, in the air, and in the vacuum of high altitude, to what kind of training must the crew of the submarine have to handle such a sophisticated system. The technical problems were immense, and the management problems were equally gigantic, but Admiral William F. Raborn and his team, through the systems approach, were able to carry the program through to a highly successful conclusion.

One of the important things they did was to project the technology - forecast future capabilities - so that the systems would not be quickly outdated. In the same way, the Telephone Company has always planned its system so that the inclusion of new technologies will not make it necessary to redo the whole system.

A similar kind of approach is used in the National Space Program, and I think that most of us are more familiar with the infinite detail associated with the flights of our astronauts, because of the opportunities we have to watch the countdowns and launches on television. Every conceivable eventuality has been listed, and plans have been made for action with backup programs ready for implementation.

The whole system has been considered as one entity -- not as an aggregate of parts put together with the hope that somehow

everything will work. The probabilities that certain things will happen have been calculated, and the reliability of subsystems and the whole system itself is well known. Nothing is left to chance.

Large architectural projects are, if not already there, coming to be in the same category. The number of skills needed is increasing. Even on such a simple project as building a house in California the architect needs a geologist to determine the hillside soil structure, an engineer to design the earthquake-proof features of the house, and a landscape architect to build the garden walls and hold back the hillside. And it wouldn't hurt to have a building contractor who knows something about systems integration. A systems integrator is a key man in large systems, and it is his job to see to it that the subsystems fit together into the system as it was designed.

My house, for example, has two small heating lamps in the ceiling of one of the bathrooms, although the architect designed it with a single large one. Why two lamps? Because the plumber got there first, and when the electrician arrived there was no way to do it as intended without taking out a lot of pipe. We compromised.

But on large and complex projects with many interactions among the subsystems, compromise may be impossible, and it would be very costly or would perhaps degrade the system not to do it exactly as designed. So you tear it out and make it like the drawing with resulting impacts on cost and schedule.

Architecture has made great strides in the last few years, and it is very clear to me that we can expect marvellous and almost undreamed of accomplishments in the years ahead. And since everything with which I am familiar is growing more complicated all the time, I can confidently predict that this will happen with all of the things with which I am unfamiliar or moderately familiar. It is surely going to happen with large architectural projects. They are going to be built in new places -- under the sea, for example.

Building under the sea will bring a whole new class of problems -- structural problems, communications problems, transportation problems, and many others. I know something about the problems under the sea because my company has just built its own deep-diving research submarine and is building two more for the U. S. Navy. "What", you may ask, "is the Lockheed Missiles & Space Company doing building submarines?" We used our systems analysis and systems evaluation abilities to tell us what would be needed to operate in the deep ocean environments after we had decided to consider it as a possible line of business. The evaluation told us that we had the necessary competences in technology and management to move into this field.

There are surprising similarities between the needs for space exploration and those for deep ocean operation. For example, each works in a hostile environment, each requires life support systems, and each has problems with communications and navigation.

In our own research submarine, which is designed to dive to 8,000 feet, and has already been down to 6,300 feet off San diego, California, we had many problems to solve. Among the alternatives was the development of a material for the pressure hull, which must withstand pressures of nearly two tons per square inch. Our metallurgists established a steel formulation which gave the right characteristics within the weight allowance that our systems evaluation said we could have. Without this new steel, our deep submergence system would not have satisfied the criteria set for it. We would not be able to carry out the missions we want, for if the hull is too heavy, something inside the hull has to come out -- perhaps some electronics instrumentation that is needed for specific operations. Thus, those operations could not be carried out. Weight is more important in submarines than in airplanes -- you want the submarine to rise when trouble occurs.

The systems analysis approach sounds in many ways like the familiar concept of designing from the inside out, starting from within, where the function takes place, rather than beginning with the shell and designing from the outside in. Architects, of course, point out that this "inside-out" approach is not new to them; certain types of projects have always been designed that way. Factories, for example, must be designed around the function, and the shell comes last.

In some types of design tasks, however, the architect's influence has been secondary to the interior designer. Many office buildings, institutions and theaters tend to emphasize the artistic factor and virtually ignore the functions requirements. Therefore architects must take a larger overall role in programming institutional design and in the total integrated planning of major projects, for only the architect can incorporate the systems approach into the overall planning -- as he does in laying out factories. He can do this by bringing systems experts onto projects with him and incorporating their philosophy.

I realize that architects and architectural firms make great use of a wide range of technical skills -- geologists, engineers of many kinds, and even ecologists. But to date I think the use of systems analysts and systems engineers has been very slight. People with these qualifications exist and are available.

To accomplish the acceptance of the systems approach, the architect must join with engineers to spread the word, so that more decision-makers will understand systems analysis and the process of predetermining functional requirements, which in turn involves computer aids and the interdisciplinary teamwork of many different technical fields. With broader understanding will come more ready acceptance, and then these techniques will be adapted to the new dimensions of architectural practice so that the methodologies used to plan a cement factory can be applied to new large and important types of projects covering the whole range of a much-expanded area of activity for the architect.

This understanding should not pose a difficult transition, since these decision-makers will realize that good design is basically functional and that esthetics can enhance, but not replace function purity.

Earlier, I mentioned a new steel for a submarine hull. Studies to improve materials are constantly in process, and recent inventions and developments have changed virtually every element and component of the design and construction process. We now devise new materials for the application where they are needed and don't modify our requirements because the material isn't available. Our spacecraft of the future, making journeys to the planets

that may take a year or more, will be powered with cryogenic fuel -- liquid oxygen, liquid hydrogen, and liquid fluorine. Liquid hydrogen boils at a temperature of more than 400 degrees below zero Fahrenheit, so it takes good insulation to keep it from boiling away. Superinsulations, composed of many alternate layers of aluminum-coated mylar and insulating materials, have been devised for the cryogenics tanks of space vehicles - insulation so good that if you wrapped a pitcher of martinis with it and left it for the month of July in Arizona's Mojave Desert, where temperatures rise to 140° or more, when you came back the martinis would still have ice in them. Now, I don't know how many of you plan to be drinking martinis in the Mojave Desert next summer, but you do use insulation in your buildings, and someday you may be using insulations like this one.

As we begin to develop new materials, we find them affecting and even modifying existing systems. And we find that new materials will facilitate the achievement of objectives which previously have been unattainable. One early example of this was the development of pre-stressed concrete.

The incorporation of new materials, new designs, and new construction processes certainly cannot be accomplished with the old architectural methods. It is the systems approach that will enable architects to use them in their projects in the future.

Along with the task of assimilating these new materials and construction methods, we are faced with an unprecedented demand for large construction projects -- bigger and bigger office buildings, huge commercial and shopping centers, and educational and medical complexes. Right now one company, Manhattan's Tishman Realty & Construction Co., is building three 100-story structures.

As with space and defense projects, the cost and complexity demand the highest efficiency, because even small errors are very costly on big programs.

We have arrived today at a point in time where we have a confluence of great construction needs, new material technologies, and rapidly-rising costs.

Systems engineering techniques can, if properly organized and directed, respond to the needs of large architectural projects with new efficiencies that can offset the galloping costs of construction.

Our most pressing social, economic and growth problems center around the city, which has many of the same basic characteristics as the weapon system environment -- complexity, masses of numbers (and people), size, cost constraints, technology, and a critical national urgency. It would appear that an approach to "Urban Systems" might be similar to that taken with the big weapon systems, making use of the tools such as the big computer, without which the masses of data could never be analyzed. It turns out that the systems approach works very well on these so-called "Social" problems.

About three years ago the Governor of California, then Pat Brown, asked the Aerospace Industry in our state to respond to a competition to do systems evaluation studies in four different areas: Transportation, Crime and Delinquency, Waste Disposal and Information Handling. My company chose to compete for the Information Handling and we won it. During the six-months period of the study, our systems analysts were in every agency in the state as well as in selected county and city governments, determining what the information needs were, what the interplay was among the different users of information, and what the requirements could be in the future as California grows from its present 19 million people to double that number.

We found, for example, that unless something is done soon, by 1975, the paper file cabinets of the state would, if lined up, make a line extending from Sacramento to Los Angeles, a distance of more than 400 miles.

As you might expect, the information system for the State of California will rival in size and complexity the great weapon systems of the Department of Defense. A beginning is being made with a major segment of that system -- the Criminal Justice Information System which we are now designing for the state. On February first the State Attorney General and 300 law enforcement officers and officials from all over California did assemble at a hotel in Palo Alto for the first demonstration of a part of the data retrieval system. The computers used were in our Research Laboratories in Palo Alto and in the Police Department in San Francisco, tied together by the telephone company.

This again tells us that by identifying requirements through systems analysis, we can take advantage of developments in many other places.

A little insight into how closely related some apparently different activities are can be gained from noting that the computer program used in the Criminal Justice System is very similar to one used for retrieving documents from the 300,000 document file of the National Aeronautics and Space Agency. In fact, the Space Agency has an input-output unit in its Washington headquarters and uses our Palo Alto Laboratories' computer every morning to locate documents it needs.

At this point I want to emphasize the importance of solving the right problem. The State of California problem was not what it first appeared to be -- a problem of handling data among the state agencies. A key factor turned up by the systems analysts was the interrelationship with local government, the counties, and cities -- and involving them was at first resisted by some groups who did not understand the problem. They finally all agreed on doing it.

The problem of criminal justice is only one of those large problems in our social structure that can be attacked by the systems approach. Another one is health care. Any one of you who has been in a hospital recently knows what is happening to the cost of medical care. Eighty dollars a day for a private room is not uncommon, and it is going higher. Labor costs are escalating - nurses are being unionized. An increase of 5 cents per hour in the hospital labor force will push the patient's cost up $1 per day. Doctors and nurses are in short supply. Medicare has increased demands for all kinds of health care.

What can we do about it? One way might be to set up a Hospital Information System that will radically decrease the paper flow, including all of the records the doctors and nurses use. With the cooperation of El Camino Hospital near our Sunnyvale, California headquarters, we put a dozen analysts in the hospital to study the information flow and analyze the requirements of the hospital. It took many months, with much feedback and review with the hospital people.

The results were so encouraging that we have decided upon Medical Information Systems as a line of business, using centralized computers to handle hospital information on a regional basis. This will greatly reduce the overall hospital costs (30% of your hospital bill goes for information handling) as well as giving the doctors and nurses more freedom to do what they should be doing caring for patients rather than filling out forms. And obviously the kind of medical data that could be accumulated and analyzed by such a system will be of great value in medical research and in determining how resources should be allocated to medical programs.

Developments like this one are certain to have an effect upon architects, for the design of hospitals and clinics will change if the nature of the functions within them changes. And the application of systems analysis to hospitals is going to bring forth entirely different points of view. The systems analyst does not view a hospital as a building full of rooms with beds where sick people are treated, but as a place where sick people are exposed to a therapeutic regime which involves the movement of people, material and information.

Employment of the systems concept produces an efficient system -- not just rooms and beds. After a system analysis approach, an architect will not simply design a better hospital than the last one -- he will build a different hospital, meeting the unique requirements that have been determined by the systems analysis. The development of adequate solutions to complex problems requires removing the old constraints and thinking through what the consequences will be.

I can see ways in which, if I were designing hospitals, I would do things differently. Recently I visited an up-to-date hospital which not only had an intensive care unit but also an acute care unit for seriously ill cardiac patients. In these two areas the patients were very carefully monitored -- not only by a large staff of doctors and nurses, but by instrumentation attached to the patients for supplying pulse rate, respiration rate, and the electrocardiogram. All patients were clearly visible to the medical staff, and any problems could be attended to immediately.

On another floor of the hospital was an elegant corridor of private rooms, carpeted and quiet. All the doors were closed and the patients weren't visible. They were probably, if really sick, in more danger of dying than any of those in the special units. The question is, how do we give patients a feeling of privacy while making them easily observable by the medical staff? How can we monitor patients with medical instrumentation and still leave them comfortable?

As we begin employing the systems approach to hospitals, we must alter the traditional pattern of first designing and erecting the building and then selecting the equipment. Rather, we should first determine the functions the hospital will perform -- through systems requirements analysis, projected patient flow, logistics analysis and so on -- and then define the requirements for the appropriate equipment. Finally, we should design the building around the equipment which has been selected to satisfy the specific operating and functional requirements.

The old method of hospital design is like buying a gift box before the gift is selected. Cost-oriented hospital people have found that the old design concept -- as with the gift box -- imposed limitations of amount and suitability on its content. They are forced into making decisions of expediency or convenience -- in other words, they compromise -- rather than making decisions which will produce the best solution to all requirements, including the lowest operating cost.

So, if we are to have the efficient flow of people, material and information necessary to the economical operation of a modern hospital, we must change our design perspective and begin to look at the problem from the inside out. Based on this systematic probing and matching of services and functions, we can then arrive at various solutions to each need and recommend the proper equipment or methods to support them. Only then can we properly design the building around the hospital's functions and equipment.

I want to talk a little more about medical care -- this time from the patient-doctor point of view. We have been doing some work with the Mayo Clinic in Rochester, Minnesota. It is a remarkable place, with 1200 doctors handling 250,000 patients a year and providing the finest medical care in the world. They are interested in improving their medical-care capability, and for a year we have been working with them on a medical information system for their clinic. One approach to the problem is taken by removing some of the classical constraints such as requiring that a patient first see an internist upon visitng the clinic. (Perhaps a patient inventory can be handled through a computer-based questionnaire rather than through a face-to-face discussion with a physician.) The Mayo Clinic is a highly complex system that has today the most advanced techniques in the medical world. They want to improve them, and they have turned to the systems approach. There is no doubt about its ability to help them improve their system.

I was doing some technical reading in a recent issue of Playboy magazine, when I ran across an article by Buckminster Fuller, who spoke to you on January 11. Mr. Fuller's story contained an interesting parallel to the hospital design concept I just described. He described the "black box" being developed in the aerospace industry which will provide astronauts with all the human environmental and metabolic-regeneration systems that are available here on earth.

To develop such a black box, however, Mr. Fuller points out that "science must understand man as a process." Again the systems approach to the problem, on an "inside out" basis.

As the article says, eventually the black box will be mass-reproducible on earth, and an individual or family will be able to take one to any wilderness and enjoy essential services superior to those now available in any city complex.

Thus, the black box will constitute the first direct application of science to making man a physical and economic success anywhere in the universe -- including earth. A good test for the systems concepts we are discussing tonight.

Coming back to the urban problem, Morris Ketchum, Jr., past-president of the American Institute of Architects, recently said, "The next ten years may be the most critical in the history of our nation. During this next decade our mounting population, expanding technology, and the rapid decay of our urban centers will force changes upon the form, function, and appearance of the American city."

Mr. Ketchum is right. But what do we do about it? To achieve the ideal city, we must begin with the ideal of a city. What is it we want? How do we want it to look and to function?

Begin with these objectives, and then determine what the city should be. If we do not, if we merely go on in the patterns of the past, we will be building future slums and putting into the cities now being built all of the mistakes of the past that have contributed to the decay in our existing cities. Let us use the systems approach to look at cities not only from the viewpoint of groupings of people but from that of the individual.

There is no doubt in my mind that the urban problem is the largest -- in concept, scope, cost, complexity and opportunity -- that exists on the American horizon today. It dwarfs any space project that we have conceived, for the job of rebuilding one major city, to make it truly liveable in the sense of what Americans mean by liveable, would cost more than putting a man on the moon. Mayor Lindsay, in fact, estimated that the bill for refurbishing New York would be $50 billion -- the cost of our entire space program for the next ten or twelve years.

If ever there was a large architectural project, it is the rebuilding of our cities! If ever there was a challenge to the architect and to the builder, it is here! And if ever there was a problem to stagger the imagination of the systems analysts and systems engineers, it is here!

Clearly, the problem is a systems engineering one, because a city is a system. It is a collection of subsystems such as transportation systems, communications systems, police, fire and utility systems, education systems, and so on. It will take the systems analyst to tell us how many subsystems there are and how they are interrelated. (I am sure we will all be surprised at how large the number is.)

A city is a functional unit which must be planned in order for it to make good engineering or economic or social sense. Its network of roads must be designed to go to the right places; its homes should be built in the most habitable parts of town; its industries should be situated in a sensible manner. Schools, hospitals, churches, theaters, and museums must be placed with care -- the kind of care which goes into the results from a systems approach. A factory should not be built without thought given to whether and how it will pollute the air, how it will increase traffic problems, and how the children of its workers will affect the school system.

In the past our planning has been incremental, generally concentrating on transportation and the growth through real estate subdivisions. Future planning must include a total consideration of all the things that make up a city.

This will lead to several basic changes in function for the various disciplines:

Architects must employ more systems thinking, and they must take a more active role throughout the development of major projects;

Architects and planners must shake off old restrictions and employ the newer techniques; Architects must take the lead in bringing together the various disciplines -- city planners, engineers, sociologists -- so that they work together, eliminating the old piecemeal approach which leads to inefficiency;

Government, in the form of councilmen, legislators and members of Congress must be enlisted in the difficult but vital task of selling the consumers -- the people themselves -- on breaking with tradition, giving up the old criteria, and accepting new goals.

It doesn't take much imagination to grasp the benefits of an overall systems approach to the architectural profession and to the construction industry, especially for projects of significant magnitude such as a turnpike or freeway, a major resource development such as California's Feather River Water Project, or a new Panama Canal, a big shipyard, or a large new community development. On the other hand, many modern-day projects are of such magnitude that one planning mistake can cripple the whole effort.

As we enter a new epoch in architecture, it is important that we review the role that engineers will play. And perhaps equally important -- the role engineers will not play. Let me talk about the latter first. Engineers must place themselves at the service of the architectural profession; they must not encroach on those areas of responsibility which properly belong to the designer, the planner, and the builder. The role is clear-cut, and the approach must be straightforward; engineers should make available to the architectural profession and the construction industry the technology and methodology that will help these groups to do their jobs more effectively and more economically. But before this can be done, we must decide what kind of problem we have. Is it almost entirely technological, like the moon race? Or does it have sociological and political overtones like the urban race? What are the parameters? Engineers can help, but you can't turn the job over to them.

The systems engineering expertise of the aerospace industry does offer a great potential for the architect. This age is one of vast social change, sparked by modern technological advancement. Human and community needs are generating awesome requirements for the architect and the systems concept is one way of ameliorating these challenging needs.

Just as the concentration of research efforts produced radically new innovations in military and space projects, emphasis on a similar scale is beginning to make an impact on costs and other complex problems facing the nation's construction industry.

There are now many architects who are well-seasoned in interdisciplinary problems and who can relate the many facets of one technology to another and relate these in turn to all the nontechnological factors that make up real-life design and construction problems.

And one of the most provocative aspects is the marriage of this exotic new technique with one of the oldest industries in the world-construction. We already have some examples of the "consumation" of this marriage. I expect there will be many more -- resulting in the procreation of a whole new generation of large architectural projects.

This, in sum, is not only the opportunity but the challenge that the engineering profession is now sharing with the architectural profession and the building industry. The most significant thing we have now done is to have begun the job itself. From this point on, I feel we are going to participate in some of the most dramatic design and construction achievements imaginable, achievements which will have meaning to all of us -- meaning as the purveyors of advanced technology, and meaning as the beneficiaries of it.

No reward could be more satisfying.

QUESTION PERIOD

FROM THE FLOOR: This concept of the systems approach to the city as a system costs a great deal. I wonder if you could comment on the conflict here of priorities in relation to where we will spend our money--relating the four billion dollars a year spent, say, in space and the objectives of that over-all goal--that space taking a systems approach would be to the benefit of our whole society?

DR. NASH: Well, I don't think we are distributing it well enough now to solve the city's problems, and I don't think we will be able to distribute our money, let's say the Federal money, for the problems of the kind we are talking about here until we resolve the Vietnam conflict, for example. But I am convinced that when that problem is resolved, as it will be one day, that there is going to be lots of money available from the Federal government for attacking problems of the kind we are talking about here.

The gross national product of the United States is continuing to grow all the time, and I don't have any illusions about the taxes going down in the future; they will probably continue to go up. I think the Government will go into these big programs. Now, the priorities are going to have to be established by the people, and I think they will be through the Congress, and that something will be done about our city problems, but I don't know when that will happen. I think we are making a start.

Our Secretary of Health, Education, and Welfare just resigned because he didn't think the priorities were established appropriately, and I think he was right. I don't think we are doing well enough. I don't know whether that answers your question. I really don't know how to answer it completely.

FROM THE FLOOR: Do you feel that we would be able to stay ahead of the snowball on the downhill run and get started soon enough for it to do any good?

DR. NASH: I don't think we have any choice. The question is, will we be able to stay ahead of the snowball, and can we start soon enough to do any good? I guess the answer I give is, the longer we wait, the harder it is going to be; but I suppose we will be building new cities in the United States, and I think some day we will build new cities that we have designed before we build them; but we have very great problems in refurbishing the cities we already have and, of course, that is where things are going to start. It is going to be a long time before we catch up, maybe decades.

FROM THE FLOOR: You mentioned systems people as a new branch of engineering or something. Who are the systems people, and how do they go about their work, and what is their training? What kind of information do they have about form?

DR. NASH: They are possibly engineers, and some of them have come up through the sciences. But systems engineering is not a discipline in itself in the same sense as electrical or mechanical engineering, or any of these other special fields or disciplines. Systems engineering is really an approach to problems where you evaluate the problem from the point of view of what it is that you want to do. If you want to build, well, let's say you want to build a city; what is it that a city has to have in it? And you first have to evaluate what it is that you want the thing you are building to do, and then having decided what it is you want it to do, you must then determine what the ways are of doing it. And there are always many ways for solving any particular problem.

You establish the constraints -- a major one is almost always cost. And you then try to determine what alternative solutions you have.

Somebody once described systems engineering as organized common sense. In a certain manner of speaking that is a good way to look at it. It is being completely systematic and objective about the requirements of a problem, and then seeking the solutions to that problem. I guess the systems analyst is really a man who asks the right questions to determine what the problem is, and then makes use of all the technology and other capabilities at his command in order to define a way of approaching the problem.

FROM THE FLOOR: Haven't you just described an architect?

DR. NASH: Well, an architect uses systems analysis, that is right. The question is really, as the problems get bigger and bigger, does he need to have people who are skillful helping him define these problems?

Yes, I think the architect has to be what we call the program manager. Systems analysts don't work by themselves on these things; they report to somebody who has the responsibility for defining the problem and then determining what the solution is. He is the program manager. One of the people he has, one of the groups of people he has at his service in doing this, is a systems analyst. An architect, I think, is the program manager in the larger architectural system.

FROM THE FLOOR: What are the limitations of systems analysis?

DR. NASH: The limitations are the same, I think, as they are on any kind of a large program.

Systems analysis, as I say again, is merely an approach to a problem by trying to define all of the factors that contribute to the problem. Its limitations are that you sometimes overlook some of them.

If the problem is very large, it has to be broken down into subsystems, and then the problem sometimes changes from one of determining what the subsystems do to the overall, what we call the integration problem, putting subsystems together so that they form a working system. This turns out to be one of the large difficulties in the system, because the subsystems are often assembled or put together by people who don't talk to one another often

enough, and when you start to put them together you know that they don't fit.

FROM THE FLOOR: If I may pursue it more, it seems to me that in order to apply a systems analysis more efficiently, two things have to exist. One, that the factors, the parameters are pliable, quantifiable; and, secondly, that the factors of production are controllable, since there are certain factors of production that are neither quantifiable nor controllable. For instance, we cannot control an individual's taste. This is a sociological factor; it is very important as an architect to have this concept, and, now, how can we incorporate this set of limitations?

DR. NASH: I don't know how to answer your question because it is the sociological factors that make the architect's profession quite different from the engineer's profession. The engineer knows the laws of physics are going to apply, and he knows exactly what they are, and what the constraints within which he has to work are, and, of course, if he doesn't know exactly how an answer will come out, he can always put limits on it. You can do some of these things in your profession, but I know that you have the problem that you make the wall blue and somebody will come along and say it should have been green; you have a problem, and perhaps these answers are going to have to be put into the system with much broader limits on them.

FROM THE FLOOR: Can you say something about the dynamics of the systems approach and the need for iteration in the systems approach?

DR. NASH: The question is, can I say something about the dynamics and the need for iteration. And that is right, because when you are looking at a large system, particularly if you are looking at a system that is already in existence (and we are talking about systems of that kind here tonight), then the question that you want to ask is--what can I do to make improvements in the system?

The first thing that one does is to look at what the system is doing today; how it operates; and then ask questions of the people who are operating the system: "What things do you think will be helpful in changing the system?" Sometimes they give answers that aren't helpful.

The systems analyst himself then considers possibilities for change and improvement in the system by taking advantage of the things that he knows about the system to begin with, plus his own training--and let me call in his own training in relaxing constraints. Most people who are in an operating system have not thought very much about how the system ought to be changed. They are accustomed to working with it. It seems comfortable only to them. It may cause them lots of problems, but they really don't think about changing it. The analyst suggests that maybe there is another way of doing it. He goes back and makes recommendations, and then he goes back to the people in the system, and they sit down and talk together about how one might do this or that, and then they try again, and it gets iterated over and over until you come to a place where you feel either it is not sensible, economically sensible to continue this, and you fix that on the design; but iterating is a key part of it.

FROM THE FLOOR: Who will build the cities of the future, government or private enterprise?

DR. NASH: I hope private enterprise.

FROM THE FLOOR: Is that what you think?

DR. NASH: I think so. I think so, because I think private enterprise has the capability to do these things better than government can. I hope it is to be private enterprise. I think the architectural and construction professions will build these cities. I think they will do a better job of it.

FROM THE FLOOR: Don't you think that the large corporate entity such as you represent will be the group who will take over and do the building of the cities?

DR. NASH: No, I don't think so. I don't see why they should. I mean, there is a construction industry now. I think that advantages will be taken of the kinds of approach that I have been talking about tonight, but I don't necessarily see the companies like Lockheed or General Motors and others doing this.

FROM THE FLOOR: Of course, there is one now who is entering into this field.

DR. NASH: Well, some big companies have often entered into things where they can do stuff with mass production and that kind of thing, units and that sort of activity, but I don't see Lockheed, for example, undertaking a contract to build a new city. My crystal ball isn't perfect, but our thinking certainly is not going that way now at all.

FROM THE FLOOR: If Lockheed, for instance, decided to make a large plant near a city, that would have more effect on the city plan than anything I could do. So, it seems to me the large system of city planning is really determined by the economic, business, and sociological factors. If we are dealing with that large a design system and subdesign system, how does the architect-designed system plug into the large part?

DR. NASH: I think really the architect is the one to whom others plug in. I think he is the main key behind this.

FROM THE FLOOR: I think that would be nice, but that is not what happens.

DR. NASH; Well, it hasn't happened in the past perhaps, but I think we are talking about a different kind of world from the one we have had in the past. I hope we are. And I can't see engineers--my company is a company of engineers--and I can't see the engineers solving these problems.

I can see the architect solving them with the help of the engineers, but sometimes I think we engineers get the feeling we can do everything; but, you know, it isn't really true.

FROM THE FLOOR: In your comments on the hospital, you mentioned that you considered an efficient flow of people, materials, and information, and I was wondering what types of analytic tools you use to analyze a closed system like that or any other system in your company?

DR. NASH: In this particular case we picked some people who are skilled in this--in the application of the systems analysis approach to the hospital--and had them actually follow everything that went on in the hospital: what the doctors did; what the nurses' aides did; how medical orders went from the files to the pharmacy; how the diet problems were handled in the kitchen.

For example, it was found that when a physician had a prescription filled at the pharmacy, by the time the prescription was filled and delivered to the nursing station, it had passed through the hands of ten different people, and it wasn't hard to look at the system and see that if it was done slightly differently, about eight of those steps could be eliminated with an information system that went more directly through the files to the pharmacy.

FROM THE FLOOR: A good many architects claim that they have become specialized in planning from the inside out in the hospital field and are intimately acquainted with hospital procedure, and I dare say there are a few engineers claiming they are doing the same thing. I get the impression that what you are talking about is this, but just on a large scale.

DR. NASH: I think the answer is that you are right in many ways. That is the right answer, that it is on a larger scale, but I think it is by attacking these problems on a larger scale that we are going to get big benefits in the future.

FROM THE FLOOR: What I was going to say further is that I assume you will be using electronic devices in this larger scale. Aren't you then going right back to putting what you have saved into more costs, and aren't you also going to run the risk of a great many breakdowns?

DR. NASH; I think so. You won't be surprised to learn that those two things that you have talked about have been very important factors in the thinking that has gone on in these problems.

As far as cost is concerned, if it weren't possible to reduce the cost of operating the hospital, it wouldn't make any sense at all to try to do something like this, and the evaluations that we and others have made--I mean, Lockheed is not the only company that is thinking about these things--show that the cost can be reduced by going this way.

The problem of system breakdown is a serious one, and it does require that redundant computer systems be used, and it probably means that each hospital rather than having its own computer system will operate from a central computer system that will handle a network of hospitals. It is possible then to set up redundant systems so the realiability of the system will be very high; but that is one of the problems that we think needs to be involved in the process.

FROM THE FLOOR: Before the architect can truly lead a team which will utilize all the models of the professional members of the profession, isn't it important to enlighten the decision-makers as to what architecture on its own is--what the esthetic parameters are? Do you think your own example is apropos? You went to the big school to sharpen up on some of the administration. Do you think this might be addressed to the decision-makers so that they could find out what we are actually trying to do for them?

DR. NASH; Of course, that would be the ideal situation.

FROM THE FLOOR: But unfortunately, it is very easy for a decision maker to make a decision that he would like.

DR. NASH: Now, to make decision-makers make knowledgeable decisions rather than intuitive decisions; I don't know how to answer that question, except that I do think that as we deal with larger and larger programs where we have to work within many different disciplines, the people who are making the decisions will be the kind of people who will be objective about it; but this is an educational process that we have to go through. The architect again, I think, has to be the leader in this educational process.

I don't know how to keep people from making intuitive decisions, except the people I know who have the responsibility for large programs are usually not intuitive about these programs because there is so much at stake.

FROM THE FLOOR: Referring back to the systems approach as applied to building cities, do you see the possibility of a conflict between this approach and the human factors? Somebody would rather have the park over here, or the street over there; people have so many different backgrounds and different views as to what the city should be. Do you just visualize building this city and moving these people into it?

DR. NASH: There certainly are going to be these conflicts, and I am sure that the systems approach as I have described it is not going to solve all of the problems associated with such complicated things as cities.

The problem of cities, the urban problem, is an enormous one. I think that all one can hope is that by being more systematic than we have been in the past in approaching these problems, we can help ourselves in solving some of them, but I don't have any illusions of coming up with a detailed answer of exactly how to do it. There will always be many answers that will be useful here.

FROM THE FLOOR: Has your systems experience reached the point where you can bring together all the decision-makers on this new larger level of the city-sized project system--where you can search the country and bring together all of the municipal and institutional problems that these decision-makers face, so they can be objective in their decisions?

DR. NASH: No, we haven't gotten anywhere near that. We haven't looked at the problem really, and I don't think that we will ever be able to get exactly to that place.

I hope we can make some progress on it. It is a terribly difficult problem. I have given you the impression tonight that the way we solve our weapons problem is directly applicable to the city problem and, therefore, we know how to solve it; truly all I am saying by going at these things in this way, is that we can make progress on it--I admit the sociological problem is the most difficult of them all.

WHAT THE BUILDING PROFESSIONALS MUST CONSIDER

JOHN P. EBERHARD

John P. Eberhard is Dean of the School of Architecture and Environmental Design at the State University of New York at Buffalo. Prior to this, and at the time he gave the talk presented here, he was Director of the Institute for Applied Technology at the National Bureau of Standards, U.S. Department of Commerce, which is engaged in creating opportunities for the introduction of new technology in Government and industry. Among other projects at the Institute, Eberhard worked on the development of a systems approach to government building, and on a project to develop a research program for the Department of Housing and Urban Development (HUD), designed to develop the knowledge and test methods for writing performance requirements for low-cost housing. Eberhard came to the Bureau after extensive experience as a consultant to industry, practicing architect, and as a lecturer in the School of Industrial Management at the Massachusetts Institute of Technology.

In the 1950's Eberhard was the President and one of the incorporators of Creative Buildings, Inc. The firm was initiated to design and build medium-priced homes, but converted to the design and manufacture of prefabricated buildings, primarily religious structures. In 1959 he joined the Sheraton Corporation of America as their Director of Research and was concerned there with the investigation of data processing techniques and the application of new technologies.

MR. EBERHARD: I am going to try an experiment tonight. The system in which you and I are presently involved, this audience with me as the speaker, your response to me as the speaker, and your questions seem to me to represent a disparate set of requirements on me as a focal point.

For instance, I wrote a speech about a month ago which I intended to use tonight. It began with a quotation from Archibald MacLeish, the poet, in which he says that, "our chief failure is a failure of the imagination. We know more than any previous generation has ever known and we feel less. It is our incapacity, perhaps our refusal to feel, to realize emotionally what we know intellectually that is at the root of our trouble."

And then I went back and read the correspondence I had received from George Macomber which suggested, "we hope that you won't lapse into the normal educational syndrome and wax philosophic. We would like you to talk about your experiences, to tell us what the Government is doing about systems building and systems analysis."

So here you have one humble, egotistical man.
I have to talk about the Government without talking about philosophy, and I have to talk about my experiences separate from the Government.

So, I see myself as faced with what the Chinese philosophers call a "yin and a yang," what might be called discouragement and encouragement; and what I choose to call problems and opportunities. What I would like to try to do is to spin around those concepts some words about my experiences before I was in the government, and since I have been in the government, and some of the things I am going to do when I leave the government the first of May.

The speech I wrote I tore up because I gave it at the University of California last night. The audience, I would say, was about 15 years younger than this audience on the average, and when I talked to them about what disturbed me; of the problems of the United States; about our difficulty with feeling and being involved emotionally in the things we know; with my concern that the design professionals are a concerned profession, but not an involved profession; they didn't know what I was talking about.

So, I decided that tonight, I would talk off the cuff a little bit, read partly, and that hopefully the message would be more relevant.

I am going to start with an experience I had which I had when I was about 25 years old. Just after I graduated from the University of Illinois, one of the cow palaces that claims to teach architecture, I decided that what I really needed was experience in how to put a building together since I thought I knew by then how to put lines on a piece of paper.

A couple of other young men and myself went into the home construction business. We rapidly proceeded to lose money because we never stopped designing the houses. While we were building, we designed. The better bricklayers we became, the more we could do with brick. The better we became with carpentry, the more we could do with wood. The houses turned out to be lovely houses. The clients got $23,000 houses for $13,000, so that we had lots of clients. (Laughter.) That is one way to go in business, you know, because if you lose money on the first two houses, you take on five more in order to pay the bills on the first two.

The story I want to tell, though, occurred shortly after we went into business. A mission board of the Lutheran Church in Illinois came to me when I was out pounding nails in the cold one day and said, "We want to build a prefabricated church in Urbana and we understand you are sort of a combination architect and contractor, and we would like you to supervise." I said, "Well, I will be glad to look at it." They showed a design that had come out of a system of prefabrication, namely, two poorly designed houses stuck back to back with the walls removed between them to make it big enough to hold services in. This is what they wanted me to supervise.

I said I thought that would be a terrible mistake to build in a college town. They said, "Well, do you think you can do any better?" I said, "What are your program requirements?"

This was in 1953. They said, "We want a chapel to seat 150 people. We want it up in six weeks, because we are going to call the minister next month, and when he comes we want the chapel here. We want to be able

to take it down once the congregation is established, like the ancient tabernacles of the Jewish tribes and move it somewhere else, and we have a budget of $10,000." I didn't laugh, though I suggested I would have to think about it. I wrote them a letter and said, I am afraid that is impossible, and they wrote back and said what if you had another week and another thousand dollars?

I wrote them a letter and said in effect, let's stop fooling around and see what we can do. As a result they gave me then what I am sure every 25-year old architect in the country would consider an ideal commission. They said, "you are a bright young man, we are very busy, we will come and see the building when it is dedicated. You get it done. We don't care about preliminary drawings or working drawing or who the contractor is going to be. You know what we want to do, just go ahead and do it." That is an interesting challenge.

I remembered where I was sitting the day I got that architectural "spark of genius" and thought of the basic concept if the solution, I reasoned, that a church, at least a Lutheran church, needed height. The cheapest thing to build was a roof. We had a limited budget, we wanted to be able to take the building apart. So, I came up with an A-frame truss with panels bolted to the frames on eight foot centers.

Well, we built that first chapel by hiring another contractor. It had rolled roofing, but we designed with an artist the windows, the light fixtures, the candlesticks, the furniture, everything that went into the chapel. We got it up for $14,000. The mission board was impressed after that first venture, the company when I left in 1958 had done 200 prefabricated churches all over the United States. It had received 4,000 inquiries from all over the world; had another 120 projects underway; were manufacturing at the rate of $900,000 a year for about three million dollars worth of construction. As president of the company, I had 50 employees and a payroll of $3,000 every Friday morning. I didn't know a thing about the theory of management, but I was concerned about the implications for design in what we were doing. I said to myself, what would happen in the building industry if somebody who had management skills and who had money decided to do something about industrializing this process?

You know, here were a couple of runny-nosed young boys who didn't know what they were doing, weren't stopped by building codes or weren't stopped by the labor problems, weren't stopped by the prospect of marketing prefabricated buildings to churches, (can you think of a tougher thing to market?). We had competition from United States Steel Company who spent $200,000 trying to market a prefabricated church in 1955, and then sold only ten of them before going out of that business. I believe we succeeded because our system wasn't a hardware system, our system was a way of doing things which resulted in hardware which adapted itself to the client's needs.

We seldom did two buildings that looked exactly alike, but every building we did had a 'family' relationship to the other because we had a concept about how we manufactured these buildings-- a system of production and design.

Well, now, I want to go back and talk about what I think systems means and tell you why I think that this prefabrication idea was not a particularly intelligent performance on my part.

Systems for me, and these aren't always original thoughts, can be looked at either as a noun or thought of as a verb. In the sense that a system is a noun, it is a thing, but not one thing. One thing is not a system. There has to be at least two, and more often there is a large number. Those things we can call components. However, any collection of components is not a system. A collection of components that has a relationship between all of the components that is capable of being described and understood based on some inherent unity is a system.

A system can be as large as the solar system. If one talks about the solar system, one needs to include all of those components that go into making up the solar system. If you leave out two or three of them, you haven't described the system completely, and if you talk about only two or three of them, you haven't talked about the system completely. So, it is the wholistic quality of the solar system which makes it a system. Or one can talk about a system as small as a molecule, in which the electrons, the neutrons, their orbits and their properties, represent the system of the molecule. When we use the word system in the building industry, we usually mean something made by man. The difficulty then is to be reasonably rigorous about what it is we mean when we say system.

Well, systems can also be a verb, a way of doing something; but once again it is not just any way of doing something. Just because one says I am going to use a few steps that I am going to go through and say that I am using a systems approach doesn't make it a systems approach. If you are being rigorous, the systems approach means that one goes through some sort of process which promises results. So that if I talk about a system for betting on the horses, I promise you that if you use this system, you are going to come off better than if you just used the laws of probability. Or I can talk about the Euclidian system of geometry as a system which says that if you accept the assumptions, and if you follow the rules, I can explain to you, and you can explain to yourself, the relationship between points, lines and planes in space.

The systems approach as it could be applied in our industry is borrowed for the most part from space and defense industries, from people like Jack Nash and his company, who was here to talk to you earlier. There are a couple of cautions, though, about assuming that that technique is transferrable. The first caution is that many architects will assume that this is what we have been doing all along. I don't think that is true at all, and in a minute I want to go back to my story of the chapel to show you why. There are also cautions for the scientific types, the people who have not been in the building industry, who may assume that we know how to state our problems. By and large, our statements of the "problem" are not very sophi-

sticated nor based on much knowledge. We ask the client for a statement of his problem and his understanding and his intelligence about his problem. His statement is probably based on preconceptions of what it is that he thinks he wants.

The steps that one would presumably go through in any kind of systems analysis are as follows: 1) a statement of a problem; 2) the invention of alternatives; 3) the selection of a measurement means for evaluating those alternatives; 4) the evaluation of the alternatives by these means, and then the recirculation back to a restatement of the problem, or the invention of new alternatives if none of the alternatives that you have at that point in time meet the test of the means; 5) the actual implementation of the solution selected, and, finally; 6) an analysis of the solution in order to produce feedback in an iterative way, so that the next time you go through a problem of this kind you have some knowledge that you did not have before.

Well, let's go back to look at my chapel experience. The first question I faced was a statement of the problem. I gave you about as much statement of the problem as there was. The Mission Board wanted a building which was portable; they wanted it to be up in six weeks; they had somewhere in the neighborhood of $10,000 (or as low a cost as possible); they wanted to seat 150 people and take care of whatever functional arrangements they presumed that I knew they would need to hold a service in the Lutheran Church.

That is not a very adequate statement of the problem, because it wasn't based on a body of experience. For instance, as it turned out later the concept of portable chapels was a blind alley. Just like the temporary buildings we have on the mall in Washington, they don't become very portable or temporary once they get built. The "low cost" everybody was interested in, but no one was clear on what they meant by low cost. The body of knowledge on which the problem was based was essentially the intuition of the client reinforced by my own limited knowledge of Lutheran liturgy. Later I want to discuss one way to get at a more adequate problem statement.

The second step I indicated was the invention of alternatives. Well, that is an interesting process that many architects go through in various ways. In this case it all happened in my head. I remember the rocking chair that I sat in for about an hour and a half while I posed to myself alternatives, and then I scribbled some of them on paper. I seized on this idea of the A-frame chapel, and from that point on, all other alternatives were excluded.

The technological sophistication of the alternatives that I was able to pose to myself was limited by my breadth of knowledge, which wasn't very large at the age of 25. I was comfortable in working within wood frame construction, so that's as much as I examined. I wouldn't have posed to myself the alternative of light steel frame construction or extruded aluminum or Bucky Fuller's dome. I knew how to work with dimensional lumber, and that was the technological limits of the alternatives that I explored.

There were no means to test these alternatives except economic constraint, and by the time that really was going to be tested, it was too late. Just like my houses that I talked about earlier. It was possible to build them once the economic constraints became realized at my expense, not the client's. Therefore, the next step, that is, applying a means of measurement to the alternatives, was not possible; was not even conceived of by me.

The fifth step, the implementation, was done within the technological constraints that were available. I want to talk about technology a little bit more; so let me define what I mean by technology for this purpose. I mean by technology the sum of the ways in which a society provides itself with its material objects. It is not those objects themselves. It is not airplanes and highways and automobiles and bridges, it is the sum of the ways in which a society goes about providing these objects. At any point in history, those ways are determined by a collection of elements.

The first element is the skilled manpower available to it. That manpower in the case of buildings ranges all the way from people with mechanical skills to people with intellectual skills. The next are the organizations and institutions which employ these professionals. The third are the resources of that society, both its natural resources and its financial resources. We often assume that we are not bound by natural resources in the United States, simply because they hardly ever become a constraint; but it is obvious that there are instances where they do become a restraint even in our society. For example, I have been part of a panel in Washington which has been looking at whether or not the electric car is a feasible solution to air pollution. One of the major constraints here are natural resources because the technology of producing batteries is based on precious metals; silver, cadmium and metals of that kind. If all of the automobiles anticipated to be on the road in a year like 1980 or 1985 were powered by batteries there are not enough precious metals in the world to make those batteries. There is a resource limitation on some of our alternatives.

There are also financial resources, and those are limited at any point in history and at any time in absolute terms and in psychological terms. A nation distributes its financial resources in various ways and by various processes to the things which it presumes are most important at that point in time. I think it is clear that it is not simple to work back from resource allocations to problem solving and expect automatic results. I do not believe we can decide as a nation, as we are trying to do now, that we have a problem with the technology of housing, and, therefore, we will put lots and lots of money into the problem and solve it. It doesn't work that fast, because in order to solve problems of this magnitude, there needs to be new institutions and new corporations and many more skilled personnel. If the array of skilled personnel at any one point in time is either limited in absolute numbers, as it now happens to be in the skilled building trades, or in imagination (in terms of knowing what the new technological opportunities might be) then money isn't going to make that much difference.

My argument is, and some people buy it, that at this point in time in this country there is not a technological solution to low-cost housing. The only viable alternative for the present is to make up the difference in income some way between people whose incomes are low and what it costs to build houses. For that reason, I would not give any grant to any university, to any other organization, which says if you give us a hundred thousand dollars, we will show you how to build low-cost housing. They can build 20 units or a hundred units or 500 units, but if we are talking about the inventory of housing the President talked about in his housing message, the 6,000,000 low-cost units to be built over the next ten years, we don't have the technological capability of solving that problem. We don't have it because we don't have the kinds of skilled manpower, the kinds of organizations and institutions, the resources, and laws and regulations and traditions which relate these elements to one another and make it possible to have a major shift in our technological alternatives.

The last step in the systems approach was evaluation of the solutions in order to have feedback possible. That never even occurred to me in my chapel experience, until we had about 75 or 80 of these buildings spread out all over the country, and we began to get complaints. Then we went back to look at these buildings in order to find out what some of the things were we had done wrong in order that we didn't repeat the same mistakes. That is one of the advantages of being in the manufacturing business that architects don't have. I don't think architects really benefit by their mistakes collectively, but they do individually. When I was in the Industrial Management School of M.I.T. one of the professors that I had there pointed out to me that after 3,000 years of building technology, we were capable of building enclosures to surround the production of rockets to take us to the moon, but those enclosures still leaked. This is not a very good feedback system if after 3,000 years there still isn't sufficient knowledge to avoid the problem of leakage.

The practical experience I want to tell you about next is a project which my Institute for Applied Technology is working on with the Public Building Service. The Public Building Service, among other things, builds government office buildings, some of which are down in Scollay Square here in Boston.

What we proposed to the Public Building Service more than a year ago was to work with them on a systems approach to the building of government buildings on a demonstration basis. We are now through about the first step of the six steps I described in the systems approach. We have been working a year and a half. We have spent $250,000, and we now are beginning to believe we can describe the user requirements. If they had posed the problem to us as architects, we would have had to accept Public Building Service's statement of what the problem was. Our model would have to be the conventional office building, and our constraint would be whether or not we could do it within better costs. Better costs are part of our process of systems analysis and by better costs we mean cost effectiveness. Not just first costs, but life costs and, more importantly, operating costs.

Those of you who work with hospitals, know that the first cost of a hospital is matched after something like 18 months by the operating costs of the hospital; so that if you could increase the first cost of the hospital and reduce the operating costs, you would have much more of an impact on the cost effectiveness of the hospital, or if it was possible to increase the performance of the hospital as a tool for medicine, even though the costs were the same, the solution would be more cost effective. That is what we are going to try to do for government office buildings.

It is interesting when you begin to ask yourself, what is a government office building for? What are the user requirements? And who is the user? It is clear that there is not a user. There is a hierarchy of users. The Commissioner of Public Building Services is a user because he is responsible in his position to the Congress and to the people of the United States to get office buildings built, to operate them as landlord for the Federal government, and to do so as efficiently and effectively as he can within all the constraints he operates under. There are also the people who are going to be the managers of the buildings in the city in which they are built, who are responsible for things like client satisfaction in terms of providing them with heat, light, water and space, and keeping the buildings maintained. Then there are the people who work in the buildings.

We have had people like Ned Hall, the anthropologist, working with us trying to help us explore what we mean by user requirements. It is pretty clear that if you talk about what a government office building does in a city like Boston; there is even a different set of questions. That is, what does it mean to the people of Boston?

As I say, we are only through the first step, because the second step is going to be one of going to industry, not to architects immediately, and asking industry to pose hardware systems solutions to the performance requirements based on the user needs. We are not going to specify what this building should be made of or how it should be made at this point in time; we are simply going to try to describe what the building ought to do in terms of the user's requirement. We are hopeful, we are more than hopeful, we are encouraged by the response we have gotten so far, that industry is going to be prepared to make some investments in developing alternative hardware systems responsibe to these user needs.

The next step is going to be the evaluation of those alternatives, and that is going to be tough. We are going to have to settle for imperfect measurement tools. We are going to be able to measure very well the insulating properties of the wall system or the structural strength of the structural system, or the fire properties of the columns, but we are not going to be able to measure very well what this is going to mean to the satisfactions of the secretaries who are in the typing pools in this building, and we are not even going to be able to tell very well what it is going to mean to the people who are going to have to maintain the building ten years from now. We are certainly not going to be able

to measure in any rigorous way, what the impact of this building on the community will be other than its economic impact.

When we have gone through this step, the next step will then be to go back to conventional, if you want to use that word, architects and engineers; what the public building service prefers to call AE's, who will be asked to design a set of government office buildings with the constraint, if you consider it a constraint, that they use the hardware systems which have been proposed and which have been selected on the basis of evaluation.

The buildings will then be built and, hopefully, most hopefully, we will go into the next step. That is, the buildings will continue to be evaluated over their lifetime in order that we can begin to develop a basis of knowledge, not only about things like structural properties, but about how people use this building--what we thought we wanted in the way of performance and what is actually happening in the way people use it.

We have another project which we are working on that I would like to tell you about. This project is to develop a research program for the Department of Housing and Urban Development designed to develop the knowledge and test methods for writing performance requirements for low-cost housing. It is not an easy problem. We don't even know what the terms "low-cost" and "housing" should mean. We have been exploring for two weeks with some pretty good people what housing means, and it is pretty clear that if you look beyond the conventional wisdom that exists in building codes that says this is what the house has to be and ask what it ought to do, that we have few answers.

Building codes have a number of requirements that, as far as we can tell, are based on superstition. No buildings have fallen down yet, so that the structural requirements are presumed to be adequate.

For instance, many codes specify 16 inches on center for studs in a frame wall. Ezra Ehrenkrantz tells the story, and I hope I am not stealing his thunder, that the way this was arrived at was as follows: When plaster was first developed in England back before the turn of the century, in order for it to be installed on walls, a cheap lathing material was needed.

Prior to this point in time, the brick manufacturers in England had standardized on nine-inch fire bricks. The only heating in English houses was fireplaces, and they were standardized in their design. There were two bricks in the back of the fireplace which made it 18 inches wide. The industry for developing fuel to burn in these fireplaces had developed and cut its lumber 16 inches long. That was a cheap source of supply for lathing material, so naturally the uprights were put 16 inches on center, and now it is a requirement in the building code.

That is one that we have begun to do some work on in the National Bureau of Standards. What we have been doing is developing knowledge and test methods that would make it possible to describe what the structural properties, the thermal transmission properties, the acoustical properties, the surface hardness, the vapor transmission properties, etc. of the exterior walls of a house ought to be.

Given these performance requirements and the ability to measure them, American industry would be free to invent walls made of green cheese or spun aluminum or lumber. Innovation would then be much freer. What we still don't know, and what we are not going to be able to put into these performance criteria, is what the walls that make a room means to a mother with three children, or what it might mean to a style of life for a low-income family who lives in the slums. We really don't know. In fact, we don't know how to begin to require that kind of knowledge. I hope that this has been reasonably practical so far. With your indulgence, I'd like to wax philosophic in closing.

It seems to me that systems and the systems approach, both as ways of doing things, and as alternative technologies, may be used to solve the problems in our society. There is something much more important as far as I am concerned, in considering the concept of using the systems approach as an opportunity to do something we have never done before, to consider systems as a chance to build the physical environment--dense urban places that we call cities--with performance characteristics unimagined in prior time; with performance characteristics that will enhance all of our lives, not just the lives of the low-income portion of the population. If such systems could enhance all of our lives, and I think we are likely to make this kind of investment in the next two or three decades, then, what we are doing is making an investment in the physical environment that we can pass on to the generation who will inherit from us in the 21st Century.

Therefore, I believe there is an individual, a professional and a societal challenge here. I have some quotations I would like to read on those three kinds of challenges.

The first one is the individual challenge which comes from Geoffrey Vickers. He says, "We all have some responsibility for action, some area, however small, in which each of us, and he alone, can play the part of agent." There is a second field wider and not congruent with the first in which each of us can contribute to the making of policy. There is a third, wider still, in which each of us has power to give or withhold the sense of policy decisions to others. There is a fourth, yet wider, in which the only responsibility of each of us is the neglected, but important responsibility of giving or withholding the trust which supports or inhibits our fellows in the exercise of their inalienable responsibilities; as their trust or distrust supports or inhibits us. There is a fifth field: the creative function which shapes the work thus and not otherwise; whether the work be a building, or an institution, a nation's history, or a human life; here lies the possibility for the vision that is manifest for good or ill. Whenever a state of art is imposed on a state of nature, "the authentic signature of the human mind." I think that the authentic signature of the human mind is what Archibald Macleish has called imagination, and that is what designers have as their property in trade. That is what they can bring to the processes.

My plea is that what we needed to try to do through our policies and programs is to enfranchise design as a part of the processes of our lives, so that design occurrs and is capable of occurring in all of those processes. Until that happens the designer is not involved no matter how much he is concerned.

Most architects, and I assume all of us, are concerned about the quality of the kinds of housing that is built in the United States, but we are not involved. Less than three percent of the housing that is built in the United States has an architect involved in it. We can blame that on all kinds of people. We can suggest all kinds of constraints. But the fact remains that we are only concerned; we are not involved. That is the professional challenge.

Then there is the social challenge on commitment. There are people who are pointing out the difficulties and there are other people who are pointing out the opportunities. Lewis Mumford points out the difficulty. He says, "No society can escape the fact of change or evade the duty of selective accumulation. Unfortunately, change and accumulation work in both directions. Energies may be dissipated, institutions may decay, and societies may pile up evils and burdens as well as goods and benefits. To assume that a later point in development necessarily brings a higher kind of society is merely to confuse the neutral quality of complexity or maturity with improvement. To assume a later point in time necessarily carries a greater accumulation of values is to forget the recurrent facts of barbarism and degradation."

On the optimistic side, Eric Hoffer in his new book says, "The fact is that the mad rush of the last hundred years has left us out of breath. We have no time to swallow our spittle. We know that the automated machine is here to liberate us and show us the way back to Eden, and that it will do for us what no revolution, no doctrine, no prayer, and no promise could do, but we do not know that we have arrived. We stand there panting, caked with sweat and dust, afraid to realize that the Seventh Day of the Second Creation is here, and the ultimate Sabbath is spread out before us."

I agree with Hoffer and with Mumford. I think we are at a point in the building industries of the United States where we are ready to shift our processes, but we don't know how to get into the next phase of technology. Some of us are afraid that this technology shift won't come, others are hopeful that it will not come. It will mean transition for us if it does come. I am afraid it may mean a move towards degradation if it doesn't come.

You remember the poem by Longfellow, that began, "Sail on, oh ship of state, Sail on, oh Union strong and great." Do you remember the next two lines? I think those are the lines which should indicate the path of our concern, as people who are involved in the building industry, because the next two lines say, "Humanity with all its fears, with all its hopes in future years, is hanging breathless on thy fate." Thank you.

QUESTION PERIOD

FROM THE FLOOR: Mr. Eberhard, would you clarify your relationship as an architect in Urbana to the manufacturing process for this chapel you are talking about?

MR. EBERHARD: I should have made more of a point of that. After this first chapel was completed, I decided contrary to the American Institute of Architects that the way to help control the process was to be in the production of the artifacts that went into it. I don't think I was all that rational. I was really concerned about how I was going to survive financially. We were asked by the Lutheran Church to come to a national convention to let other mission boards know about this idea, because they thought it was such a hot solution to a tough problem and that there must be other people who would like it, and being young and 25 and in financial difficulty, we wrote a booklet which we passed out, because you have to have things to pass out at conventions, saying that we were in the business of manufacturing these buildings if anybody wanted to buy one. We weren't, but we said we were.

A lot of people accepted the pamphlets and some of them scoffed and some of them said it was interesting, but nobody signed the contract. In fact, we didn't even have any contract forms, but about two months later when three of my partners had left and it was down to one partner and myself and an office girl who managed our money, a couple of men walked in off the street one day and said they were from a mission board in Nebraska and they had been authorized to buy one of our chapels.

Well, 45 minutes later they walked out of the office with a contract and I went to see my friend the lumber dealer. (Laughter.) And said, look, I got a bona fide contract; will you support me to the extent of giving me lumber to manufacture? We went out and got a little printing plant that had been abandoned, and we went into the prefabrication business on a total working capital of about $3,000. That is not an industrial process. You know, people talk about the trailer industry as being an industrialized solution to housing. You know how much a trailer manufacturer has got to invest? About $100,000 in capital equipment and $250,000 in inventory, and he is paying about $8 a square foot for 10,000 square feet or larger plant. That is not a capital intensive process. If you are going to drive down the cost of housing, you are not going to do it by that process. You can cheapen it or decrease the space or provide less costly solutions, but you are not going to reduce the cost of housing, in my judgment, with that kind of investment.

My figure, which is as good as yours, and maybe better because I have talked to some people, is that the investment that it is going to take is 500 million dollars. Now, that is not a lot of money when you compare it to space programs. Jack Nash's company makes those kinds of investments. They have that kind of cash, and so do a lot of other companies. The hitch is not the 500 million dollars, and that is what I say it will take to make a capital, to invest in a little research, the development of a lot, and the capital equipment to reduce the cost of housing by 25 percent, which is the sort of magic goal. The hitch is not the 500 million dollars. The hitch is, what would you expect as a reasonable return if you invested 500 million dollars?

If you take the Xerox Corporation and what they get as a return on their investment and what they get as a percentage of their sales, you would have to sell 200,000 housing units per year. If you take a very low income that is return on capital industry, eight percent, and figure four percent on sales, it comes out somewhere around 50 to 75,000 housing units per year. The largest builder in the United States, Leavitt, has a market of 5,000 a year, and then it is a sharp drop down to the next company. That is a magnitude of ten off.

I don't think we can organize a market. I don't think it is possible at this point in time to organize a market which you can guarantee to the entrepreneur in order to get him to make that investment--a market of from 50 to 100,000 housing units per year for ten years. And there are a lot of companies which have looked at this and have shied away when they see the problems of creating that market, and I don't think the Federal government--that is, Congress--is about to give anybody $500,000 to upset the balance of power within the traditional building industry. That was a long answer to a short question. Did I answer your question appropriately?

FROM THE FLOOR: Only partly.

MR. EBERHARD: All right, what was the rest of it?

FROM THE FLOOR: Did you get into the manufacturing or distributing?

MR. EBERHARD: Yes, we did. Once we got this printing shop operation going, I think I indicated briefly before that that was in 1953 (and it is still in business today and doing very well without me) we started a manufacturing operation which employed 50 people and did a volume of business of about $900,000 a year. They are now up to something like three million dollars a year and doing very well.

FROM THE FLOOR: Following that context, where do you place the architect in this technological process?

MR. EBERHARD: I think the reason we were successful at that scale with those kinds of problems--that is, churches--was because we were architects, and as I indicated before, the system that we developed was a methodology of manufacturing components which was so flexible that we could adapt what we did to each new situation as it came up.

United States Steel failed when they tried because what they came up with was a package, a prefabricated church at a good price, and presumably you bought that church or a variation on it, and that was it. The fact that we were architects, or maybe we should call ourselves designers in order not to offend the AIA, although I did have a license, made it possible for us, I think, through our design initiative and imagination to adapt the manufacturing process to the problems rather than vice versa.

FROM THE FLOOR: Mr. Eberhard, if you had a universal building code throughout the whole country and all the local building codes broke down, do you not believe that there would then be an incentive for this 500 million dollar investment you say is impossible today?

MR. EBERHARD: I am not sure. Building codes, as I indicated, were not a problem. They were a problem to us in the company that I was the head of, but we were always able to solve the problem.

Building codes, as they stand right now, are chaotic. There is no question that there is a huge variety. There is no question that they sometimes and very often are a deterrent to innovations. But my judgment as an individual now, and not as an employee of the National Bureau of Standards, is that where building codes are a real problem is to marginal improvements. If you want to substitute plaster bathtubs for enamel, they are a problem. But if all of the other constraints were out of the way and you produced a house that really cost 25 percent less at sufficient volume, I think cities would go out of the way to remove the building codes as a restriction in order to let you bring that in as a solution to the problem of low-cost housing.

FROM THE FLOOR: Assuming that you met your deadline of May 1 for these performance standards--

MR. EBERHARD: Oh, no, we are not going to have them, we are going to outline a program of how to get at the performance standards.

FROM THE FLOOR: Okay, what can you expect HUD to do on May 2?

MR. EBERHARD: Read the report. (Laughter.) No, they will do more than that. It depends on what Congress does for HUD next year. HUD has their request in for a research and development budget which is the budget we are working out of--20 million dollars--and that sounds like a lot of money in this industry. Of course, it is not much when you talk about a nine billion dollar research budget for the Defense Department, but the intent of our contract here is to outline the cost and benefits that would be presumed to come from performance requirements along the lines that were just raised--that is, if a shift in codes were made to a performance basis, what are the implications as well as we can deduce them by the 1st of May, that this would have for the cost of housing them?

Secondly, what performance criteria and test methods are now available that could be implemented immediately? What performance criteria and test methods might be developed over the next year or two years if an investment was made, and where are the organizations and universities and institutions who could do that research?

And then thirdly, what performance requirements and test methods are likely to take ten or fifteen years? And what is the order of magnitude of the investment likely to be?

Simply because our knowledge base is so slight now that we are nowhere near being able to do it, that is all that we hope to do by the 1st of May, which is ambitious enough in itself.

FROM THE FLOOR: Have you had a chance to look at any systems in Russia or England?

MR. EBERHARD: I have. I have not been to Russia, but some of the people who work for me have, and there is an interesting--I think it is all right for me to talk about this--there is an interesting report that we have prepared which makes the following argument. If all one was interested in doing was deciding how the Government could most efficiently drive down the cost of housing, look at what Russia has done.

The Russians have by a process of central management, which is presumably not what we want, organized their market of some two and one-half million houses a year as a market. They make the decisions on a central basis about what resources are going to be allocated to this.

Some of you may know what I am saying here, but for those of you who don't, one of the performances that have come out of this system which is as impressive as hell is the new city of Bratsk that was built in Siberia. And eight years ago it was virgin country. There were no roads, no airfields, nothing. All there was was a very large waterfall, and the Russian government decided to build the largest hydroelectric dam in the world, and then the largest aluminum plant in the world, because aluminum, as you know, requires large amounts of electric conversion from bauxite to aluminum. They, therefore, wanted to build a city for 250,000 people.

The way that was done, and I will use the word prefabrication although that is not a good word, was to prefabricate the industrial plants, which were shipped to Siberia, and to prefabricate the buildings. And the efficiency which was gained by this organization of resources and industrializing of the process resulted in four men being the field crew who assembled 400 apartments 12 stories high. If you take the labor content that went into the production of these apartments all the way from the mining of the cement to the transference of that cement to plants in Siberia, to the labor that went into the manufacturing process in the plants, and the labor that went on in the field--if you take those man hours and translate them into the dollars that are paid for the equivalent skills in America, those units end up costing $3,500 a piece.

The units include two bedrooms, a bathroom, a living room, a dining room, and a kitchen. And although I haven't seen the actual buildings, from the photographs I have seen of them, they would appear to be adequate for not only low-income families but for moderate-income families as well. The asthetics of the Russian construction is something which we, of course, can easily take pot shots at.

My impression again from photographs and conversations including a very interesting one with Ambassador Dobrini who is a brilliant man, is that their first problem was a problem we may be getting to. After World War II the male population in Russia from which one would have drawn the skilled professionals to build the buildings was essentially wiped out. That means that the buildings that had to be built had to be industrialized not because this was going to drive the cost down, but because they just could not have been built any other way. There just weren't enough laborers around in the building industry to get the buildings built.

Asthetics, was sort of superimposed as what Archibald Macleish calls an adornment to civilization rather than civilization, but over the last 15 years they have begun to improve the asthetic packaging of these industrialized buildings.

Joe Keane was telling me earlier, and he is somewhere in the audience, I think, that in Boston next summer the volume of construction now on the boards and out for bids is going to be short of the skilled labor market. There aren't going to be enough skilled men in the craft unions I presume, available in the Boston are to get the buildings built that could be built.

I think this is a problem which is not yet acute, but one which, if all indications are to be believed, will be acute in the next ten years, because the age bracket from which we draw our skilled journeymen, roughly 25 to 50 years old in the male population, is getting to be a smaller and smaller percentage of the total population. There are more and more people under 25 and more and more people over 50. A large percentage of the male population, larger every year, is going to universities and so far, people who graduate from universities have not gone into the building trades, even though they pay better. (Laughter.)

If you couple this with the fact that new families are being formed by children who are already born who are here and who are living at a rate which is going to require just to meet their demand, that we build something like two million houses a year, it seems to me we are going to be forced to some sort of productive efficiency in order to meet this demand with the production capabilities of our country.

FROM THE FLOOR: I have two comments or questions really. One is, what comments you might have with regard to the recent McGraw-Hill report on the urban crises and their statement which in essence is directly opposite to the point you are making tonight.

MR. EBERHARD: Are you from McGraw-Hill?

FROM THE FLOOR: No, I am not. (Laughter.) They made the comment that it is not a technological problem, and everybody has been waiting around for the technologists to solve this problem, and it is not going to come. It is strictly a money problem, and the Government ought to get busy.

MR. EBERHARD: That is what I just said, I thought.

FROM THE FLOOR: It is not clear to me why money really couldn't solve the problem. You said there would be a shortage of labor, and even if you had the money, you couldn't pay the people because there wouldn't be any people there. This kind of bothers me because I read, for example, Stanford Research Institute's report with regard to the industrialized process, and, to a certain extent, a lot of the labor isn't removed from the industrialized building; it is a certain shift from on-site labor to in-plant labor; but the total volume of labor isn't reduced all that much, at least according to the report. It is not clear to me that the industrialized building is the key to reducing the amount of labor required, because it seems to me even industrialized buildings don't appear to do that.

ME. EBERHARD: Okay, let me feed back to you what I think you said, which I don't think we have any major disagreement on, but only some misunderstanding.

What I said is, I didn't think an infusion by the Federal Government of money into the housing field with the intent of driving down its cost by technological innovations was not going to be successful at this point in history. Money should be made available, and the only rational basis upon which it could be made available at this point in time, I think, is to subsidize or in some way or other make up the gap between people with low income and the cost of housing.

Now, on the fact that our industrialization of housing or of building processes so far has not produced significant results, I think this is true. And that is the reason why I say we can't pump money into it, because we don't have the inventions, the innovations, the imagination; we have got imagination, but we need application of the imagination, and the entrepreneurial wherewithal to make a shift in the technology that is going to produce any dramatic savings. And I guess my own concern is that we don't get hipped on that problem, because I think that problem conceivably could begin to go away in the next ten years. That is, people with very low incomes.

And even if it doesn't, there may be other social means of solving that. But, in the meantime, we are not looking as an industry at the opportunities. What we can do to increase the performance capabilities of our buildings and of our cities to enhance all of our lives. The easiest way to understand this is to retrogress. If you go back to about 1880, 1890, there are a number of significant inventions that occurred: the steel skyscraper, the telephone, the automobile, the electric light, the subway, refrigeration, plumbing and its applications, that made possible high rise, densely populated urban areas. There has not been, as far as I have been able to find, one significant invention since then; 60 years ago was the last time we made any major inventions that contributed to the technology of the physical environment in which we are building, and I don't think it is an accident that if one asks to whom would society turn to for these inventions, that the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Architects, the American Chemistry Association, the American Physical Society, the National Fire Prevention Association, all were formed prior to 1900, or that all the engineering universities except for their new extensions, and almost all of the architectural schools, were founded prior to 1900. I don't think there is an accidental relationship between the technology that is available and the professionals who are associated with it. What it does say to me is that if we are in for another wave of major new inventions which will increase the performance capability of our urban hardware systems, that we are likely to get a new breed of professionals along with it.

FROM THE FLOOR: Aren't you better off in asking the Government to spend its money creating the situation which will produce the new professions or the new institutions, if you will, that were produced in the late 19th Century, 18th Century, which has made very prolific kinds of activities possible? Isn't that the leverage of years ago of our financial assistance?

MR. EBERHARD: I am writing a so-called paper for the Douglas Commission, the National Commission on Urban Problems, in which my subject is supposed to be urban technology, and I go back to the elements I mentioned before; the professional, the skilled manpower, the organizations, institutions, resources and the rules of the game which control their relationship to one another. And what I am trying to talk about in this report is what I think the Government might do about supporting the kinds of changes that could occur in these constitutent elements in order to increase the alternatives that we have available to us ten years from now.

But I make the point in the first paragraph, this is not a solution which is going to solve the problems next summer, but in order that we don't have those problems each summer for the next ten years, I think we need to begin to make certain kinds of investments now in order that eight or nine years from now we can increase our alternatives, and my professional prejudice is we don't get those alternatives by inventing new products until we invent, modify, and produce new processes which are capable of a larger number of alternatives.

FROM THE FLOOR: At the expense of seeming to be quite technical again about this, we are all quite aware of the manufacturers' efforts to produce systems of ceilings, of walls, and so forth, and they attempt to incorporate within the discipline of their system a certain amount of flexibility for a certain range and so forth, and yet I seem to detect that very many architects feel that they compromise their true professional performance with a client if they limit themselves to using that kind of thing. Would you comment on that?

MR. EBERHARD: I think this is partly illusory. If an architect thinks he has a great deal of freedom now, then he should put his Sweet catalogue in the back room somewhere and never look at it. I think the larger scale the project is, the tighter the budget, the less freedom he has. If you have a client who has $60,000 or more to build a house, then you are probably not limited by a confined spectrum of technological products that are on the market; although it is not very likely you are going to create a whole new set of doors, probably doors and windows. And if you go to a major project like a Government office building, the probability that you are going to be able to have Seagrams for a client and invent entirely new solutions doesn't happen very often.

So, it is a trickle down process it seems to me that the architects have, if they have much at all in the way of influencing product changes. The components are controlled by people with other kinds of design talents, if they have design talents at all. What I am an advocate of, and have been ever since I wandered around the halls of MIT in 1958, is modifying the process, not just to let the architects in, but modifying the process in such a way that the design professionals who relate our ways of feeling to our ways of knowing are capable of extending their talent to as broad a spectrum as possible of the processes and to as broad a portion of the population as possible. In fact, I think it should be all of the population.

If we have a social responsibility, if we accept what Lord Bowdin says, that the can should be tied to our tail, then we can't say that we are meeting that responsibility when 95 percent of the housing is not being done by design professionals, and only a small percentage of the rest of the buildings are being done by design professionals. Design professionals to meet a social responsibility, if that social responsibility is to be as broad as relating design skills to the total growth environment, means that they have to be involved in the whole process.

FROM THE FLOOR: In your report, at this time, could you indicate whether or not the low-income houses are going to be single-family houses or multiple housing types?

MR. EBERHARD: Which report, I am sorry?

FROM THE FLOOR: I mean, this study.

MR. EBERHARD: The performance criteria?

FROM THE FLOOR: Right.

MR. EBERHARD: Well, as they were given to us; that is, the user groups, there were three groups: a group of low-income families who live in urban areas--that is essentially a multi-family multi-story building solution; a group of rural poor, and a third even tougher group of low-income Indian families who live on reservations. And if you just think for about two minutes to try to develop the user requirements for 500 different Indian tribes--(laughter)--on any conscientious basis, you realize you need another week and another thousand dollars. (Laughter.)

FROM THE FLOOR: You spoke about the financing. Where do the insurance companies come out on this with their contributions to urban housing? You spoke about profit return and so forth.

MR. EBERHARD: I am not sure what you mean.

FROM THE FLOOR: The insurance industry is backing housing, are they not?

MR. EBERHARD: You mean the million dollars they agreed to provide?

FROM THE FLOOR: Yes. Where is that going to come out, and could this be enlarged upon? You say money is the question.

MR. EBERHARD: Got any bankers in the audience? (Laughter.) I am not going to take Bobby Kennedy's prerogative and say no comment except for the following. (Laughter.)

As far as I am concerned, the innovation capabilities within the housing field are now controlled by the people who own the capital, and that is the bankers and the insurance companies, and all of the pleading, concern, or involvement that design professionals, even home builders or even people who own the land, who are the ones who are really making the money may make about this, isn't going to make any major difference until there is a change in attitude or a change in the rules which relate to the people who own the money, to the processes of building houses.

Now, maybe we don't want to change that, and if we don't change it, I think we just have to recognize it as one of our costs.

Well, let me close with a joke, I hope--(Laughter.)--that is apropos to what I just said. This is an environmental joke which is slightly indelicate, so I hope you will pardon me.

A soldier is lying on the floor of a barn in France during World War II and a small bird comes hopping by and the soldier sees the bird is shivering, so he decides to be friendly and in order to provide him with a warm environment, he cups his hand and holds the bird in his hand like this, and soon the order comes that he has to move out, and so he then has to cast about him for alternatives, and the only alternative that appears to him to be reasonable is that there is a pile of fresh manure in one corner of the barn that is still steaming and he reasons to himself, if he puts the bird over the manure and he puts his helmet over the top, this will create a warmer environment, and this he does and he is correct, and he leaves and the bird begins to chirp merrily and there is a cat prowling around and he hears the chirping, and he knocks the helmet off and sees the bird and catches it and eats it.

There are three morals to the story. One, it is not always your enemy who gets you into it, and the second is, it is not always your friends who get you out of it, and the third one, apropos to what I just said; if you are in it up to your neck, for Christ's sake keep your mouth shut.

THE S.C.S.D. STORY

EZRA D. EHRENKRANTZ

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Ehrenkrantz is a member of the National Commission on Urban Problems and is on the Research and Engineering Advisory Council of the U.S. Post Office Department. He is also on the National Advisory Committee of the Massachusetts Institute of Technology and is active in the Organization for Social and Technical Innovation in San Francisco.

MR. EHRENKRANTZ: I have been filled in briefly as to the discussions of the previous speakers, and can only say as we begin tonight, please overlook any overlap. I am sure there will be some.

At the present time, I would like to think that we are at the beginning of what might be called the third era of systems building. The first era was essentially one of building with proportions providing the basic discipline. The Greek temples, works of Palladio or Alberti had a very tight discipline in the way in which buildings were designed. The modular formation of the Greek temples, with the length to width ratio of 2-N + 1, provided a basis of proportion related to people who could cut stone to any particular size and put the stone together in institutional buildings, whether it be in temples or later in churches.

During the Elizabethan times we find a careful development of what was a very pragmatic approach to construction, wherein products for residential construction were sized quite effectively to human dimensions and requirements. The width of a brick was that which a man's hand could span, approximately four and one-half inches. Its length for bonding purpose, twice the width, or nine inches. The fireplaces in the earlier Elizabethan houses had a width the size of two bricks or 18 inches. When fire wood was cut for these fireplaces the normal dimension was 16 inches, and as the wood lath tradition came into Elizabethan construction, the fire wood was cut to the same length, making a 16-inch lath and plaster tradition and a 18-inch masonry tradition.

The impact of these traditions can be seen today in the 9-inch vinyl tile in this room. The sizes that were developed out of a craft tradition are in force and in use today.

The implications of the products we use relate directly to the craft beginnings in terms of sizes, shapes, proportions; but we are working with machine products that must be disciplined in size and proportion in terms of the way in which our building products are developed today.

And so we must have an opportunity to progress from these initial beginnings into perhaps what might be called the third era of system building.

Our process today is improved in the ways in which we make our products-- the machinery that we use; but the disciplines tend to be very much that of a craft type of industry. There is very little simulation in the design process to predict what it is that we are going to build in terms of its eventual performance and relatively little feedback by way of providing a solid base from which we can learn from experience.

The last airplane which was built in this way was put into use in the early 30's. Since the 30's all aircraft have been designed to meet particular performance criteria. It is not a matter of building them and finding how they would work. If we built the airplanes today the way we construct our regular buildings, we would have an interesting situation. By taking the low bid for the assembly of a lot of different components, the engines, the fuselage, et cetera, from a group of different subconstractors and assembling them at the airport, probably none of us would enter an airplane designed and produced under these circumstances. We really need not worry, because it wouldn't get off the ground.

If we are working within an industry wherein we are concerned with buildings of social purpose which have considerable cost constraints, this basis of working has some major problems. One must work with standard products and not alter things done by machine at the building site, but the sizes of the products have been related to previous craft conditions, and not to our current needs.

One may believe that in the design of individual buildings there is a great deal of flexibility, as represented by the palette of Sweets catalog. You can choose any structural system you wish when you begin to design a building, but if you make the choice that for a particular set of requirements a four foot six inch module is right, and you begin to look for lighting fixtures and ceiling components that are standard and will fit, you have some difficulty; and the choice in terms of progressive decisions within the design of a building decreases rather rapidly.

Much of what we call contemporary architecture as seen in magazines requires the custom design and fabrication of products, and it is perhaps for this reason, along with many others, that there is great difficulty in meeting basic problems and designing housing. There are obviously many other reasons: tax policy, financing, land cost, et cetera, but this is one of the factors.

There are difficulties particularly evident in California. I don't know how far things have gone here, but shopping centers, industrial work, etc. have moved very much out of the professional realm in terms of design. These are facilities where people believe that package buildings and other approaches will provide the best

value for the building dollar, and facilities which should be designed to meet the particular needs of the client are not designed in that way, very much to everyone's dissatisfaction.

We find at the present time in California a major onslaught in terms of educational facilites. The portable classrooms of three years ago are being grouped together to provide not only elementary and high schools, but total junior colleges. The ability to do the work fast, the fact that the price is guaranteed before the college signs the contract for the design of the facilities, and many other factors obviously relate to this. There is a battle, and there is a need to show that we as architects can provide, on the basis of individual design, physical facilities that will meet the needs of our clients in a way that enables us to compete with any form of construction if we are to remain current.

While we are being subjected to a certain amount of competition by the rising interests of the aerospace companies, particularly in terms of the West Coast, the uncertainties of the building industry, problems with building trades, building codes, and understanding the role of a fire marshal, bedevil people used to working in a more orderly way.

These companies are not able to proceed too effectively at the present time through their civilian systems divisions, but I think as we look toward the future it is possible that as the rate of change continues to accelerate, we will find our technology developing in new ways. There is interest not only in terms of using the computer for design purposes, but also in computer-developed machine tools which can fabricate products to any edge condition and to any size. When the ties are made, the possibility of having a completely different level of competition between the traditional way of working, in terms of craft industries, and the techniques which will be current makes one wonder whether it is possible for control of the building process to remain in the hands of the design professionals. It is vital that the major developments are in fact organized and run by professions not for their own being and not because of the Jehovah complex of any of the professionals, but rather so that a group which has the interests of the client first and foremost in mind, instead of the dollar, has the controlling voice.

If we are able to maintain control through progress in new methods and techniques, I suspect companies such as Ford, Boeing and Lockheed will not be in vanguard. This is not their business. The level of diversity which one has with the computers, as far as Ford, for example, with its 22,000 models of the Mustang is concerned, is superficial compared with building problems.

In terms of meeting real needs we must have a keyboard which permits basic variation rather than superficial variation in the way in which buildings are designed. I suspect and hope that a Ralph Nader will not be needed in the construction industry ten years hence.

Working in the National Commission for Urban Problems I had the opportunity to visit cities around the country and to interview various people. It is quite obvious that things are not working as they should in terms of the provision of our physical facilities.

We find, in fact, that the people who play the strongest role in defining the problems within our cities are the people concerned with health, whether it be lack of ventilation or lighting, rodent control, or diseases that may be bred through the poor development of the physical facilities, their maintenance and use. We find that it is the people concerned with public health rather than with design who are putting the brakes on deterioration within our cities.

To pose the problem the opposite way, it is almost as if architects and others had to object to leprosy because of the aesthetics to the people walking around our cities. These are things that we should be dealing with within our own fields and disciplines. The fact that we are not, is not because there isn't a will to do the job properly. There are obviously tremendous numbers of people striving to provide first-rate facilities, to update and renew existing facilities, but in many ways we are not making it. If this is true, we have to begin to look at the context in which we are working. It may be necessary to try to change some of the institutions in our society if we are to find clients and opportunities to serve it properly.

If we take a look at the building process as it works today and see some of the barriers to innovation, we might find that one of the places where a starting point might be made is within a traditional competitive bidding situation where each job goes out to bid separately. The chances then, of anyone being able to innovate in an orderly basis are great.

Even if a company bidding for public work spends a lot of money for research and development, comes up with new products and puts them on the market, when it comes time for bid, at least two other companies who have not done the work would have the opportunity to bid on the plans and specifications. The people who have not invested in research and development would obviously be in the best position to get the bid, as they did not have their costs to amortize.

If you are designing projects one at a time, you try to come up with new products, get them on the market for the first time, bring them into use, and then assume the work might be done. The constraints that a general contractor faces in using techniques which have not been previously tried in a one-shot situation for a single building, obviously necessitate contingencies which must be added to the bid. Because there is no opportunity to develop experience, good new developments cannot be amortized over time.

We have problems in designing a building on a completely one-off basis because the market itself is not large enough to permit research and development costs to be regained and each building must be designed with a completely new configuration. To this we must add the problem of getting tests done rapidly. If you have a new way to wire a building and you need

an underwriter's lab approval, the waiting list to get a test done is nine months. If an architect has a good idea germane to a particular design, he may submit it for approval. However, he cannot go out to bid until he gets the approval and he cannot get it before he has to go out to bid. All of these factors, and many more, tend to militate against an orderly research and development process within the building industry coming up with new products and new processes by which we can build our new buildings.

In this respect, we have tried to make some institutional changes in the way in which projects are built to see if by changing some of these procedures we can make possible research and development work which otherwise would not have an opportunity to get off the ground.

Perhaps one of the first and major aspects of this work is to create a viable market. The fact that the people who may comprise the market have definite needs may be attested to by the S.C.S.D. Project; 13 separate school districts joined together to build specific schools four or five years hence with non-existent products, which would be designed to non-existent performance specifications, which would be written when the user requirements were developed.

Anyone who has served on a board of trustees for a school district can understand that this type of commitment by a public body indicates that all is not well with the current facilities. Thirteen school districts agreed to work together in this way, providing a market that eventually turned out to be about $30 million worth of school construction in a single package. We then had the job to try to understand the requirements, working with teachers, the directors of curriculum and other people involved in education. Based on this we tried to translate the user requirements into performance terms to make it possible for manufacturers to bid, and then to sponsor the work and run the project for bidding and testing to see that the requirements were in fact met.

Performance specifications provide an opportunity for each company and individual that takes part in a process to take advantage of the innovation of that company or individual. Each bid was on a completely different design. Parity was through performance and as all of the performance tests or all of the performance requirements were subject to tests, we had a valid basis for competitive bids.

Through our field testing we know what the performance is, so that we then have a valid basis for evaluation. Obviously, many of the requirements were hypotheses in terms of what we expected to be adequate to the job or to be appropriate to the job. When we set requirements for the sound transmission characteristics of a wall which might be used between two classrooms, we test to see that the characteristics are met. We can then go back and find out whether the sound separation is adequate. If it is not, we can raise the performance criteria and thereby provide for feedback. In this way we can gain from experience in a controlled way, continue the development overtime, and improve products as we go along. We are just getting ready, and hopefully this fall we will have the opportunity to begin to evaluate the schools in use.

We have developed some new techniques with respect to costing and on our current student housing project we are no longer taking bids in terms of first costs. The bids will come in in terms of the annual cost per student. This is a composite figure related to the amount of money that it would take to amortize first costs, the amount of money that it would take to maintain the products that will operate in terms of both cleaning and in terms of energy, and the amount of money that it would take to alter the facilities as inevitable changes take place.

One may ask, how can you be sure that the maintenance requirements can be met for the price bid? We couldn't. So, we require, for example, that the people bidding in the air-conditioning field give us a 20-year maintenance contract.

One of the most interesting things was that instead of being looked at sideways, we were thanked. The people representing many of the companies indicated that now they would be able to sleep at night. They didn't have to worry about what was going to happen in buildings where they kept shaving the quality in order to try to get the bid; rather, they could look at the problem in terms of the actual costs, and this provided a much more interesting and exciting engineering problem.

As we take a look at different approaches that may relate to change, we unfortunately find most people in two separate groups. One group looks at how things are done today and provides very minor changes based on the way we do things at the present time. In terms of the types, requirements, and large orders of magnitude needed for change this approach is insufficient to meet the problem. There are others who have a tremendous image of what the future might be and can paint a picture which is exceedingly bright, but how we get from where we are to that point is rather difficult to postulate. I think the most important requirement is to be concerned with those types of experiments that provide a ladder that you can move up rapidly and provide opportunities for rapid evolution. In this respect we hope that the types of experiments that we are engaged in can be looked at in the light of being experiments and only that.

In beginning the work on the S.C.S.D. Project we considered about 16 strategies and chose only one. We have used the same strategy on our student housing project, although we are now engaged in other projects using completely different approaches. By this I mean to indicate that there are many different routes, and obviously many that we ourselves didn't even think of. However, the need to try to work in different ways, I think, is paramount if we are to develop a group of choices from which

professions will have an opportunity to pick in terms of future directions.

I would like to begin to describe the approach that we have been using in S.C.S.D. and in the University Residential Building System, URBS Project, as we call it. We are concerned with developing performance specifications and user requirements, which are a compromise of the costs which obviously have trade-offs in terms of what you can provide within any given budget situation. However, what can be provided for is obviously modified by the technology that can be made available.

If this technology is not on the open market, it may be hidden in the back rooms of different companies. It is interesting to note that what comes out of the back rooms of most companies is like an iceberg. Unfortunately, it is marketing people and sales managers, rather than the research people, who determine what is put on the market and very frequently this is in terms of what they think they can sell. If you develop the basis of working in performance, all things begin to occur. Directors of research from different laboratories call up and say, "in your next project, would you please ask for this? We can do it." But it is only if somebody from outside asks for it that we will have an opportunity to do it. Because of this we become concerned with developing our mix of user requirements and costs within a potential technology that can be developed, and what industry may be willing to develop depends on the size of the market; the carrot which one may hold up for industry.

This carrot has two forms; the initial volume of construction within a given project, and the opportunity to use products developed for the project across the country.

If you can generalize the requirements in such a way that they are not only appropriate for a given volume of construction on which bids are being taken, but are generic to national problems, it is much easier to get industry to make major investments in research and development work.

From these factors obvious trade-offs are made and performance specifications develop. The performance specifications themselves may have a major influence in terms of the design of any products, and I think the examples that I will illustrate this shortly.

Once the performance specifications are put out to bid, within this process we have opportunities to evaluate the developing designs of different companies without a price being submitted.

It is relatively easy to make addendum modifications to throw out submissions that obviously do not meet the specifications, or the intent of specifications, when there isn't a price on the table.

The performance specifications provide the basis of the system. The components, which are successfully bid, become perhaps the initial system; but over time other products may be developed, and products of one company displaced by those of another. The common thread remains the performance, and the system itself is the performance specifications rather than the hardware.

In this respect one must begin to look at the performance not only in terms of what must be done, but how it should be done, and become concerned with developing a keyboard for design. The amount of variety, and the place where the variety will be found in the design process for any given project, must be determined as performance specifications are written. Analagous is the way that Bach liberated and made possible the development of a tremendous musical literature, and the development of a system -- whether it be the proportional system of Palladio or the Greek temples -- that provides certain kinds of opportunities for design and design composition.

In our own efforts to work out a system which can be compared with this type of keyboard, we begin to see that there are opportunities to develop a relationship between the different products, product sizes, and that there are opportunities for great design freedom and variety in the design of individual buildings.

The components that have been developed through S.C.S.D. for the projects, for example, have done everything that we have asked them to do in performance. So, if in certain respects they appear not to be successful in design terms, I think one must criticize their performance much more than industry's performance, because they have done everything that was asked of them.

In setting the requirements for bidding, we are concerned with the development of what we would call compatible components, that is, products to do different jobs, different subsystems: air conditioning, structure, lighting, ceiling, partitions, different portions of the total building to be bid together on a compatible basis.

We are not impressed with the cost of a structural system that potentially saves five cents per square foot, if it results in the cost of the air conditioning going up 50 cents a square foot in order to penetrate the spaces left within the structure.

We are concerned with the total compatible low bid. In doing this we find that all of the companies bidding for component subsystems try to develop compatibility, although their edge details may differ in some respects. In this way we find that alliances can be made and broken, and in the jobs following the completion of the S.C.S.D. project, we have found all types of mixes. There are, for example, about five structural systems competing with each other, and most of these are compatible with each other by cross reference.

The performance specifications have to provide the guidelines in terms of the interface, and the relationship of one component category to another. In calling out the requirements at the joints we provide a basis by which different manufacturers can design products in such a way that they will be compatible with one another.

What I would like to do next is to illustrate the concept through two of our projects. I will start with the student housing project. We are now in the bidding process with Bids due June 6.

The University of California, our client, has committed itself to build a minimum of 4500 student places on a maximum of eight separate campuses. As we are now working between the minimum volume of 4500 and the maximum of 9000, I suspect that the numbers will be more like 7500.

The University has been concerned by the fact that the tremendous increase in student population has resulted in considerable residence hall construction. The previous volume of residence halls was low and did not provide a financial fly wheel because the students pay completely to amortize each residence hall. Students' rents have been climbing much faster than the cost of living.

Projections are that by 1975 over 20 per cent of the eligible students within the state of California will not be able to afford to go to the University because of charges which are too high. Because of this one of the major requirements of the University was to reduce the costs of current residence hall construction.

At the same time the University is faced with other problems. Vacancy rates are beginning to climb in residence halls only eight years old. On the basis of a 3 per cent amortization the college housing fund program called for a 40 year payoff. What is the University going to do in the year 2000 when these buildings (which in some cases were obsolete the day they were opened) still have one-quarter of their amortized life to go? And so the University has become very much concerned to have an opportunity not only to provide a fixed facility at opening, but to provide options for future change within the facilities to meet changing requirements.

These requirements may be attributed to educational needs. It is now predicted that the computer terminals will be a norm within residence halls in the relatively near future. I understand at M.I.T. some of the residence halls are currently constructed with terminals available. On this basis one is going to find substantial numbers of graduate students living in residence halls. Teaching assistantships, and research assistantships will include half an hour of computer time, from 3:30 A.M. to 4:00 A.M. every other Monday, and this will be part of the mix.

Interestingly enough, the philologists are going to need the terminal as much as the engineers. So, we are not talking of technicians alone. We are faced with many other changes in terms of direct dial access from student rooms, or from common spaces shared by a number of students, to the reserve book room of the library. We find the students themselves have many ideas about the way in which they may wish to live.

When many of you went to college, double rooms and double loaded corridors were no problem. When we did our homework on the kitchen table with the radio going in the background, we became used to a lot of noise. However, when many of today's college students find the family grouped around the television set when they have to study, they retire to a bedroom and so are less used to working under noisy or distracting conditions. In a university study, it has been found that in 80 per cent of the time when two students are sharing double rooms, one student is out of the room, because they cannot stand to work together. Yet all people are continuing to build our residence halls with double rooms, on double-loaded corridors, with furniture bolted to the wall, because in that way the FHA loan fund will pay for the furniture. If you can move it, they won't. Two things can be moved: desk chair and the bed. To express the individuality of the various students, a very substantial number at Berkeley pushed the bed against the door and crawled over it to go in and out of the rooms.

So, as we take a look at these problems, we find the University interested in new flexible facilities which would be less costly, and would provide for levels of environmental control, to entice people to live in the buildings the second half of the useful life of the residence halls.

It was with this background that we began to work on the project.

(The following portion of Mr. Ehrenkrantz' presentation was accompanied by slides.)

Basic requirements don't necessarily change quickly. The requirements for light, for heat, for space to work, for storage might be considered universal; but outside of certain basic requirements, there are obviously major differences.

One must study the ways in which students work together and their life in general. You can then begin to develop a hierarchy of relationships of the way in which people work and live together.

When you analyze this in terms of patterns by working with a substantial number of different residence halls, you find some strange things. Forty students, for example, sharing a single gang bath. We investigated to find out why this was done, because obviously it was not for particular social purposes. There are better places in which to meet.

We found that the average cost per student for a gang bathroom was $300. If you had a small shared bath for four to six students, the first cost would be $450, half again as much. When four students share a space, they police it themselves and clean up, but when 40 students share a space, they do not, and maid service costs $30 per student per year on an average. At 3 per cent, this means that each dollar in annual cost is the equivalent of $20 in first costs and the $300, therefore, becomes $900. The shared baths' first cost is half that of the gang bathrooms, and so our requirements are calling for shared baths for groups of students at this point.

Student rents cover the costs, and the only major factor of concern is what the annual costs are per student. The University does not intend to consider this a business and make money on the students Their only concern is to provide facilities and get their money back.

As we began to look at the problem we studied perhaps a hundred and fifty different residence halls and a topology begins to appear. You have the double corridors, the core plans, what we call the vertical houses

with different groupings off staircases and the large point towers much like an office building. We become concerned with developing the requirements for a system so that any of the different building types could be constructed using the components that eventually must be developed.

We obviously must also look to constraints that might be imposed by a fire marshal or other regulatory groups, and we have been able to make the following types of accommodations: Up to 10 students can share a space of up to 2000 square feet with no fire-rated partitions. The partitions we are using are all incombustible. They are one hour demountable partitions which can separate flexible living areas, each holding up to 10 students.

Now, through the moving of the one-hour rated demountable partitions, the FLA's, the flexible living areas, are flexible and can be moved as well.

We then began taking the disciplines and the modules that were developed to lay out all of the residence halls designed on any campus of the University of California.

We also had programs for hypothetical projects related to different options that the University might wish to use in terms of new programs for design.

We began to group certain requirements within the system to develop certain disciplines. The bathroom, the air conditioning, the places for electrical power distribution, for communications systems, were earmarked in terms of quantities and the ways in which they could be developed within the different building forms that might be used.

An area for ten students could be developed as a dormitory or the space could be divided into ten single rooms and a shared lounge. It could have double, single, triple rooms, split doubles, any types. Literally, if the University would permit it administratively, a group of students could get the space with the components on the floor and set it up the way they wished.

If you have one hour rated doors you can then join groups together of larger than ten students to share common facilities, and the basic requirements were called for so that we would have an opportunity to turn over space design for single students to apartments which could also be single student apartments. The mix will change over time.

The percentage of graduate students on maturing campuses increases vis-a-vis under graduate students and, therefore, the percentage of married and single students change over time and so the opportunity to change becomes important if one looks to full occupancy over time.

The concern with changes, if they can be accomplished readily enough, may be used in some cases for families who will come in and live while re-training programs are developed during the summer months. Thus residence halls have an opportunity to gain revenue during this period, thereby helping to reduce the actual student rents.

When we got into the program there were five major areas where we felt we had to do our basic work to develop new components. Obviously the structure becomes important, as it provides a matrix on which all the other components must hang or relate; the air conditioning, partitions, bathroom units, and furnishings were other areas that were considered important.

We set forth our requirements so that the bids will come in on a compatible basis and we will be getting the low bid for a combination of structure, ceiling, air conditioning, and partitions.

We also were concerned with the total performance of the system. We do not care what the lab rating for sound separation of a wall might be; what the lab rating might be at the ceiling; we are concerned what the in place performance will be and particularly the joint between the two, because this is obviously the major point of weakness and so all of our performance requirements are developed around field test techniques and based on this kind of testing .It then becomes possible to assess responsibly if there is a lack of performance. If you test the walls, the ceilings, separately, and you go in and the building does not perform, who do you blame? And there has been no test for the joint between the two.

We have develped weighting factors. We don't care what the ceiling to floor dimension is, but the increased cubage of deeper structural members or larger air conditioning spaces results in costs averaging out at two cents per inch and depth per square foot of the building. Exterior wall and other products will have this increased cost if the depth is greater. If one group of people come in with 60 inches, the weighting factor against their bid will be $12.0 per square foot and they had better have an awfully efficient structural system on that base.

On the other hand, if someone comes in with a system at 12 inches and 24 cents, they may have some problems meeting the grill criteria for sound on the air conditioning system as they try and move air at high velocity through obviously miniscule ducts. So that within the system there is an ability for different companies, for different professionals working together to meet a given set of criteria in their own way with a basis of parity developed, so that the University's major interest, which is to get a building system developed that will perform at the lowest cost, can be met.

For those things that are not part of the basic system that we are building, criteria must be developed and are part of the performance to permit passage of services, for example; so that vertical and horizontal distribution of electrical power to any point within the building is provided by acceptable methods as part of the component systems.

We find some interesting things as we go into residence halls. The average cost for replacement of ceiling tile in a U. C. residence hall runs about two and one-quarter cents per student per year.

There are substantial numbers of holes which are kicked in walls one way or another.

Again, these costs add up, and by analyzing the problem we can come up with performance requirements which, except for vandalism, should cover the majority of the cases wherein damage occurs, which in effect adds to the rent. Just a simple example, if door closers are provided with elbows sticking out into the corridor, we find that two students sharing a room each will be paying a dollar a year because of damage.

Many people are rather fond of turning on these closers as they find they can trap the inhabitants of the room. When you take a look at the $2 per closer per year and multiply it by 20, we have 40 more dollars for closers. We can consider concealed closers with the cost to the students remaining constant, and you begin to have a different ball game when you figure in this way.

We are calling for up to 13 story construction with a "type 1" construction, and are using a "type 4" construction for some of the low-rise facilities.

Within the process we are allowing for a substantial number of different approaches on the part of manufacturers, contractors, architects and engineers who are participating within the design research development effort. So long as they meet the total performance requirements, they will have the opportunity to be acceptable.

And again there are the basic criteria, loadings et cetera, that must be met.

As we get into the air conditioning system, there are all of the parts and the criteria relating to the parts. Within the occupied zone we are calling for temperatures of plus or minus two degrees to be maintained at any time.

We are calling for a door that will meet a STC classification of 27. It is awfully interesting to see how many students complain about sound separation within residence halls, acoustic privacy, and we find walls being built thicker and thicker and the air conditioning systems being designed by mechanical engineers with the door under cut, so that the corridors act as the return.

If one begins to develop the criteria, then all of the aspects must be taken together: criteria for air motion, grille noises, or the ability to have operable sash while maintaining this type of performance.

We have had a number of instances where fixed sash were provided for residence halls because of the fact that the buildings were air conditioned and the students unfixed it. You know, you can learn in different ways, and hindsight offers some great opportunities for learning, but it does give the mechanical equipment manufactorers fits.

We have the individual control zones which can be cooled or heated. There are requirements for 12 separate control zones within any FLA to be occupied by a maximum of ten students.

In addition, the space had to have the ability to be re-zoned in the future; if studio apartments were used, up to five separate recirculation zones were needed so that cooking odors need not be shared.

For location of equipment, where spelled out, weighting factors are developed in terms of the amount of floor area which might be used for equipment. So, again, different mechanical options from package units underneath the window to complete central systems could be bid one against the other.

In terms of partitions we called for a wide variety of different surfaces. We called for the ability to take out the panel in the middle of a run and replace it with a door or to move the panels as we have basic requirements for demountable partitions.

The partitions must be designed in such a way that the trim will act very much as a frame to hold what we have called student supplied veneers in place--cloth, paper, et cetera. If a girl wishes to go out and buy red velvet, she may paper her room with it. When she leaves, she takes it. Men students may wish to put fish nets from the top trim to top trim, providing a new ceiling for the hanging of beer cans and other things.

We have been concerned with the ability to develop a system that will provide opportunities for the people who are living within the residence hall to take possession of the space.

All of the requirements for different conditions must be called out.

We require that hanging suspension systems be part of the basic partition system, so that case work can be hung on the walls, for example, and in fact, one of our performance requirements calls for the largest case to be hung on the wall, its door open full, and a 200 pound person to chin to the extended door with a maximum deflection in the partition of an eighth inch and no set.

In terms of bathroom units, we have had some rather interesting criteria. We found, for example, that here is the place where we have, outside of the air conditioning system, the biggest maintenance cost. This is the two and one-half dollars per student per year cost. Usually the water damage on the floor below begins after between six and nine years and then tends to reoccur quite frequently, and so we have called in effect for an extended shower pan which has a drain with all of the fittings fitting into, or flushing into the pan.

We became quite involved in the design detail of some facilities.

We found in talking with various students that there were some rather considerable interests in using the tub as a place to read. The shower obviously one uses to get clean quickly. And so, due to the fact that a shower needs to be wider than a tub, we began to work with contouring the back for reading to develop a working surface. Naturally, we are going to have right and left handed rooms.

So the students will have an opportunity to study at leisure. We have discovered some rather interesting facts as well. One of the reasons that people in group situations do not use tubs relates to the debris left in the tub by the previous person using the facility, and as everyone knows with water coming in and going out, the same end of a tub, when you turn the water on, the debris floats upstream and when you let it out, it stops in the place where it began.

The reason that the outlet is normally not at the opposite end is because that is where you sit, and it is not particularly comfortable, but by having a shelf, our requirements are to return the water underneath the shelf thereby providing a flushing action through the tub so that it becomes self-cleaning.

We have a wing wall on which to supply hot-cold faucets, and so one does not have to put a hand under a hot shower in order to cool it off; grab bars for going in and out are part of this. We accepted completely the Cornell bathroom study requirements for a lavatory and so as a girl washes her hair and water drips off her elbows it will go into the sink instead of onto the floor. If we expect the students to clean up after themselves, we have got to be concerned with the way in which the facility performs.

In terms of the case work we have a variety of different systems, shapes, interchangeable components, so drawers, shelves, and other things may be interchanged.

We found that there were some rather interesting storage requirements, and when you take a look at what the average girl requires when going to the University of California and compare it with the average male student, you become a little concerned over the fact that in every residence hall built to date exactly the same storage facilities have been provided for both men and women students. You know, in this day and age, instead of getting pinned or engaged or all of the other things that may have been part of our time, giving a storage cabinet to your girl may be the sign of the future.

And through the flexibility these can obviously be mounted in any way desired on the walls as part of the hanging system.

As we take a look at the way in which spaces may be used, we find that for different sizes--this is not recommending a particular size--this is a room of 110 square feet for a single student. You begin to get permutations in terms of arrangements which are an awful lot different than the current pattern of bolting all the storage cabinets to the wall.

We discovered that some of the flexibility becomes extremely important, because as we tried to predict how students will use a residence hall facility, we find some strange things happening.

One facility was designed at Case Institute, which was supposed to be the best ever. Every student had a single room and there was a separate lounge for every six students, and this was considered quite luxurious. Unfortunately, they found out after the building had been designed with fixed walls that friendly and compatible students in groups of six performed rather poorly in terms of any academic work, and after about a year of study, sociologists finally found the major cause. Six people fit in a car and at night when one person wanted a cup of coffee, he would ask the second, and the two would ask a third, and the social pressures were such that they would all go.

Groups of eight similarly arrayed have no such problem, as they do not fit together. You know, you choose the person you want to go with and they go together. Well, so much for the concept and, you know, I think you can begin to get some kind of a feel for what the user requirements are; what the performances are; and how together they provide a base of bidding for manufacturers to meet particular requirements. And it is the performance that provides a basis of translating the needs into a format where industry can respond to the requirements.

Now, obviously this must be done within a cost context. The progress payment approach to costs where you have all of the carpenty grouped together, or masonry, does not provide a vehicle for cost control on a systems basis. You do not know whether the carpentry is for the forms for concrete in the wall or any other place within the building. So, all of our cost estimating is based on functional components.

We have costed ten characteristic residence halls of the University of California on this basis.

And in this way we begin to have the cost targets for each component category, so that we can compare them on an apples and apples basis. Taking just the University of California, and using just buildings designed over a three-year period for the one client, in each category the costs for components varied by two to one.

And again, the costs are on each basic portion of the building.

To this we add evaluation of performance. For example, you have the acoustic separation of the walls in the 45 to 50 decibel sound transmission class; for the door, 10 to 15. It is under-cut. We have some residence halls going over 55 decibels.

We also do profiles on operations and maintenance costs, so we can begin to assess the relative trade-offs in terms of costs and from this we have provided the basic target for bidding purposes for the residence hall project.

We are now out to bid. There are some 30 manufacturers and about 50 contractors involved in the process. Most of the companies have hired architects and engineers to do the design of the work.

We have, for example, the American Iron and Steel Institute developing one of the systems, and Reid and Paricks in San Francisco are the architects and engineers for the development of that system. Portland Cement Association is providing two of the competitive systems, and Hellmuth, Obata and Kassabaum have been hired to develop that particular system.

Therefore, we have a situation wherein criteria for the performance of products have been developed by professionals working with the client. As professionals, we are involved in working with industry to develop hardware, particular products to meet those requirements, and hopefully if the bids are successful, we will have furthered the individual architects and engineers designing the individual residence halls.

Now, because this stage is as far as we have progressed with URBS, I would like to switch over to the SCSD Project. I will move very quickly through SCSD to the same point and then go from there to the development work, the testing, and give some indications of what the schools were like.

In terms of education, the school districts faced similar problems. Changing educational methods, changing training of teachers, numbers, et cetera, called for rather sophisticated requirements in terms of environment and in terms of flexibility to be met within schools. At the same time, bond drives became more and more difficult to pass.

The school districts were looking for value for their building dollar, and calling for much more sophisticated requirements than they could normally obtain within the type of state aid budget to which we are building in California.

To give some idea of our targets, our current costs for a high school range about $18 per square foot. The labor costs in San Francisco are higher than those here in Boston.

As a basis of comparison, again, the basic process is a group of districts working together developing from the user requirements a set of performance specifications which were put out to bid.

The manufacturers worked to develop products and the successful bidders for each of the components were then fed back into the design process and a separate architect, working for each of the different school districts, went through preliminary working, drawing, bidding procedures to build each school separately.

We set forth the requirements for flexibility by taking example of the lighting and ceiling area.

We gave criteria for the lighting when half the lighting industry said that the criteria could not be met because of the laws of physics. We increased the foot candle levels by doubling them for particular academic purposes, while reducing the brightness ratios to a third.

We were calling for low brightness, for the ability to absorb sound with the ceiling, et cetera. We were calling for a rather wide vocabulary of different light fittings to meet the needs.

As part of the process, products are mocked up, designs are made. We have to be sure that we know at least one way of meeting the criteria before we go out to bid on anything we specify. In all cases, manufacturers came up with much better ways of doing it than we did.

And at one stage in the development of the lighting system there were three different ways of using a semi-indirect light: with the fixture in the center of two fixtures; or one hung in between covers; or luminous ceiling direct lighting fixtures. Because the manufacturers believed that the laws of physics would be violated to meet the requirements, an architect, Robert M. Ward from Chicago, emerged designer of the successfully bid system.

We called again for compatible bidding, looking for components we hoped would be cheaper, although they might perform in a rather sophisticated manner. For example, a structural member might act as a light fitting, or do the job of ceiling, acting for sound absorption or light fitting. If we could get a single item to do many jobs, it could cost a bit more and still be economical.

All the components were compatible with one another. Flexible ducts permitted the reaching of any space within the building on a five foot module. We actually revised our mock-up building seven times. One man in one hour can rezone the entire mock-up building.

As much is known about the nature of the successfully bid structural system; I will move very quickly through this. There are components which are folded for shipping which are unfolded and put together at the site. One of the most interesting things was a device made by a single manufacturer which was screw threaded to hold the ceiling level while the roof structure was cambered to drain water, and an asbestos washer broke the path for heat flow from the plane of the ceiling to the structure to obtain a one-hour fire rating.

The way in which the ceiling runners are held permits movement back and forth. So, under fire, they would not buckle and expose the structure to the heat of the fire in a flame test. Through the center of this device, which we called a spyder, one can drop conduit from the plane of a ceiling into partitions, and the bottom of the spyder has two holes which are tapped so that the head channels of the partition system can be tied directly to the spyder. This kind of development cannot take place on an ad hoc basis. You have to know what components you are tying together and how you are tying them together.

We had a multi-zone air conditioning unit and flexible duct system. A zone is being cooled; another being heated; others getting mixed air. Each zone is complete separate control zone unto itself.

In the air conditioning, the shape of a coffer can effect the ability of the air supply and return diffusers to entrain air properly. Coffer shapes were developed together with diffuser shapes so that the total performance requirements could be met.

In this project we asked for plus or minus two degrees at breathing level and at the six inch level. We found in our early studies that many teachers lead a rather sedentary life and have poor circulation. Normal air stratification causes cold feet in the winter and the teacher who has control of the thermostat can raise the temperature and put the students to sleep.

Over a period of a year we have been able to achieve plus or minus one degree as maximum deviation from the thermostatic setting in any space in the mock-up building which is a 100 per cent glass structure.

(At this point, Mr. Ehrenkrantz ran through a series of slides on the various schools in the SCSD Project.)

At the present time our 13th and last school within the SCSD Project is still to be opened. There are 800 buildings in use with one or more of the SCSD components, and bids continue to be taken on the performance specifications.

We find at the present time that the successful bidder of the structural components is no longer in business. (Laughter.) There are five other companies, which can meet the performance requirements, and the market place

determines that one product can phase in and another may phase out.

It is extremely important to recognize that the basis of a system is the response to the client's requirements, and not a particular set of hardware. This gives us the opportunity to go back coldly and evaluate how these schools have performed this fall and then to change, upgrade, downgrade, in some cases perhaps, if we called for more performance than was actually required, to change the performance specifications and begin the next cycle.

The time that it takes to build, to get used to and to evaluate is sufficient that any responsible manufacturer who bids properly can recoup the initial bids or the cost of the research and development work.

Another interesting thing that we found was that as the project progressed, there was a sufficient period of time so that we had separate bids by general contractors who had first completed one school and then went after another one. One successful bidder was second low bid by $6000 on a re-bid. There are two other cases in California and some others we have heard of since, where the successful bidder on the first project was the successful bidder on the second project. So, the experience was not too bad in that respect.

I cannot stress too strongly the emphasis on compatibility. The successful bidder for the air conditioning had a price of 3.5 million dollars with the low structural bid of 2.4 million dollars. The same air conditioning system was bid with another structural system at 6.1 million. The difference was greater than the cost of the low structural bid.

The design of products separately on an ad hoc basis as so many pieces of hardware which are put on the shelf practically daring the architect and engineer to use them successfully in the design of a building,unfortunately succeeds sometimes,and we do not use the products well. We found that in terms of our targets costs, we were able to reduce the cost of the work done by the components by 18 per cent, as compared with our set targets relating to the way in which schools were built traditionally.

As a result of this all the SCSD schools are carpeted. They have substantially more casework and many other appurtenances related to the educational performance. I believe again that this is just one way of working one type of experiment. There are many more and my plea, if any, would be to enlist as many of you as possible to become involved in experimentation. Thank you.

QUESTION PERIOD

FROM THE FLOOR: Has all this been accomplished within existing building codes?

MR. EHRENKRANTZ: Yes, it has. The work has all been done within the prevailing codes of the State of California.

One of the things that we did first was go with the public bodies for whom we were working, to the code authorities and ask what were the specific tests with respect to code criteria that would have to be met in a testing situation in case we wished to have exemptions or changes made with respect to the codes. Working with public bodies who were clients, we were able to get the code officials to sit down and listen, and they were able to set forth any test requirements they wished. In some respects we considered them slightly unreasonable, and yet having a base to work to, and having time involved within the development process, it was possible to go through this testing program, meet the criteria and gain acceptance of the products. Without the time it would not have been possible.

The other thing which is very important is that testing work in most component areas exceeded the total cost of the given component within the largest school built. The market had to be there in order to get industry to spend the money for the testing research and development. It was this which made it possible to come up with a new product.

FROM THE FLOOR: From your experience do you have a feeling on how big that market has to be?

MR. EHRENKRANTZ: I think the market varies very much with the building type that one is working in, the extent of innovation that you are calling forth and the market which might exist outside that particular initial market.

In our student housing project we have nearly twice the SCSD market. One of the reasons is that the volume of residence hall construction is much less than that of school construction, and so we had to provide a larger carrot. In this respect you have to look at each project on an individual basis and then come up with an appropriate market in terms of the innovations desired, et cetera.

FROM THE FLOOR: How long did it take to develop the criteria before you were able to arrive at this?

MR. EHRENKRANTZ: The criteria took about two years to develop. One year for working on the user requirements and another for the performance specifications and contract documents. A period of about 16 months might be the tightest that one could work to; two years is none too long. It takes some time and it takes commitment on the part of a client to go through this kind of a process.

FROM THE FLOOR: Are there any union problems in putting in these new components?

MR. EHRENKRANTZ: There are quite a few problems, but one of the most interesting aspects of the program was that we involved all of the players right at the beginning of the project.

The union representatives formed an advisory committee from the various trades which reviewed the design submissions at the evaluation stage, while they were still confidential. They were given an opportunity to complain, suggest changes, to protest in any way. Once things were accepted, they were expected to abide by their earlier decisions, and we had some interesting things happen.

We discovered that as long as you make changes which affect everyone equally, and change roles without changing status, you can do an awful lot. As soon as you penalize one group with respect to another, you are in trouble, because any group within the building industry has right of veto, whether it be the architects or the engineers, the electrical subcontractors or the plumbers. They all must work together. But given an appropriate situation, it appeared possible within this project to have major changes and literally everybody had to give. The architects and engineers had to work with components wherein they did not have their usual role in terms of choosing. The general contractors did not have the ability to select their chosen subcontractors for every portion of the work. The subcontractors instead of shopping manufacturers had to bid to manufacturers for the installation of the components. The labor unions had to accept considerable amount of factory work at the building site. We fought with every group until they realized that we were not penalizing anyone individually, but we were trying to step on all toes equally. (Laughter.)

FROM THE FLOOR: Could you make a general comparison between the SCSD system and the CLASP system in England, and did you investigate this prior to beginning your system and benefit from their experience?

MR. EHRENKRANTZ: Yes, we investigated CLASP. I spent some time in previous years working in England, so I had some knowledge of the British developments. Although I left before CLASP was begun, I went to England when the project started and met with the people involved in the CLASP project. Their project was one of developing a closed system wherein a group of products were developed together and the products were not interchangeable with the schools or any other group. This is possible when you have a client with a captive market as the county education authorities have in England rather than voluntary school districts who will work in terms of the advice of their architects.

In other words, we were operating with a completely different base. Another difference is that within the context of CLASP's closed system,emphasis is placed on the exterior walls and on the structure. In terms of American schools, we have much more by way of services. You know, the English are really just coming over to central heating, and so the criterias and the relative expenditures of money are different, and the emphasis then becomes different.

I think there are significant differences in terms of concept with open versus closed systems, and in terms of the areas where innovation was required. Flexibility and services as opposed to the exterior shell.

However, I think we owe a great deal to the work done by others previously, and there were lessons that we could learn and hopefully did.

CHAIRMAN MACOMBER: Maybe one more, because we are running a bit late.

FROM THE FLOOR: Could you give a rough percentage of factory versus site construction in the first system and what you were shooting for in the second system?

MR. EHRENKRANTZ: Our major requirement is that the performance be met at the lowest possible cost; whether it is through improving the processes on site or by doing more work in the factory, we really don't care.

In this respect, we will find, as I am sure we did in SCSD, that we will have systems which are substantially site systems being bid against others which are substantially factory systems.

To answer the question, I would have to know who the successful bidders were, but work is being done at both ends of the spectrum. In both cases, at whichever end the people are working, they are paying very careful attention to the compatibility of the components hoping for great efficiencies in the way in which the products are put in place and the way in which they do combined work.

AN INDUSTRY VIEW POINT ON SYSTEMS BUILDING CONSTRUCTION

WILBUR B. LARKIN

Wilbur Larkin is Vice President of Butler Manufacturing Company in Kansas City, Missouri, one of the oldest companies specializing in a prefabricated system of building construction. He has worked continously with Butler for 40 years, starting as a blueprint boy upon graduation from high school, and subsequently serving as a draftsman in the Engineering Department, as Chief Engineer, Sales Manager, and General Manager of the Buildings Division. He has thus been intimately associated with nearly every major development in the Butler System of Construction during this extensive period.

Larkin has been active in several professional organizations, notably the Missouri Society of Professional Engineers, American Institute of Steel Construction, and the Metal Buildings Manufacturers Association.

It is really a pleasure to be here. I have had the opportunity in my life several times of talking to groups of architects as a member of the Architectural Committee of the Manufacturing Association. We have met yearly with AIA in Washington, and I always find it a stimulating and interesting experience. Believe me, I am looking forward to tonight.

Whenever I am listening to someone talking about a subject that I think I know a little bit about, I am always interested in knowing the experience base from which this speaker is talking. So, let me just take a few minutes to establish this base, so that you might better understand why I do understand as I do about building systems.

First, I am not a Bucky Fuller, who was your speaker at the opening of this series on January 11, although I do number Bucky among my very good friends. I only wish I was smart enough to understand all of his thoughts, confusing as some of them are, at least to me. Bucky was in Kansas City the night before he was here in Boston and I had the opportunity of spending a couple of hours with him. I am sure he gave you a thought-provoking, inspiring message, I only hope that I can do as well.

In 1940, a little less than 30 years ago, Bucky was touring the Midwest with his friend Christopher Morley and he saw a number of the 36,000 circular grain bins which we had furnished the Government under its 1939 grainery program. It seems that Bucky had long envisioned a low-cost circular house that might even revolve with the sun, so that you could have sunlight in your living room all day long. From soemwhere in Illinois he called our then president, Mr. Emmanuel E. Norquist, and he briefly explained his ideas. Well, Emmanuel was a "can do anything" kind of a man. So, the result was my being assigned to Bucky as project engineer, and I had the pleasure of working with him for two years during 1940 and 1941.

We developed a circular house which Bucky called the dimaximum deployment unit. The interior was divided into segments by drop curtains. Each unit provided a housing area of about 325 feet.

One of the units erected in Washington, D.C. was featured in the June 1941 issue of "Architectural Forum" that carried a headline, "One Thousand Houses a Day at $1200 Each."

Well, we were kind of excited about this at the time, but I really doubt that it would have been a success, because I don't believe people want to live in round houses. You simply have to develop products in accordance with peoples' needs and desires, and you can't lead them too far or your timing is off. In any event, we ended this experiment with furnishing about 50 of these units for portable air conditioning operating rooms that were erected during the war in Africa.

During World War II we furnished thousands of barracks, and almost 2,000 130-foot wide combat hangers, each of which provided space by having a canvas roof and walls that were suspended from about 220 pick-up points on the frame. About three days of erection time was climaxed by raising the canvas cover in about ten minutes, which was probably the greatest attribute of this product.

The best stroke of fortune to fall on our company was that the war ended while we were producing and shipping thousands of these 40-by-100 rigid frame warehouses. We had the production facilities to match the enormous building needs both here and abroad that followed the war period, and through some product improvements, this building started what is now called the pre-engineered building industry.

In a way you could call this the start of sub-systems of construction, because our industry does pre-plan the structural elements sub-system with the wall element including necessary doors and windows and so forth along with the roof sub-system with its appropriate openings.

There was a crying need for housing after the war, and, flushed with the success we were having in the pre-engineered industrial and commercial building field, we decided to take a fling at pre-fabricated houses and developed a modest two and three-bedroom unit which we called Boulevard Homes.

Interest was so high at the time that my only concern was that there simply was not enough land in the United States to hold all of these houses that we were going to sell. I learned two things from this experience, and other companies such as Lustron subsequently learned the same things. First, the marketing of houses is unique within itself, and certainly different than the marketing of industrial and commercial construction, and you know, second, I learned that that carpenter with his modern tools is not nearly as inefficient as he might appear to be when you are watching a house under construction.

This experiment ended with our furnishing several hundred Boulevard Homes, and the biggest single order we had was for 100 houses for a development project at Bettendorf, Iowa. I recently passed through this neighborhood and these houses still look good, and they are selling at a considerably higher price than we were selling

them for at the outset. So, the product was a success. It was simply a case of offering the proper value at the proper price and making a fair profit, all of which we seemed not to be able to do, particularly on the last point. In fact, we dropped about a quarter of a million dollars on this experience.

However, our pre-engineered and commercial and industrial business continued to grow and succeed, and acceptance of this way to build led us to start development work way back in 1959 in the pre-planning of other elements of a complete building, all planned to work together with flexibility, but with certain limitations as to sizes and uses and so forth.

Each year we project a long-range plan for a five year period. Let me quote you from the plan we drafted in early 1960 looking through 1965. "The general area of complete building systems holds considerable promise for the future. As buildings become more highly specialized and more complicated, the need for a customer to obtain a carefully designed building systems becomes more desirable. A roof designed to include the heating, cooling, and lighting requirements will greatly accelerate this systems approach. This approach should not connote an inflexible, sterile design; instead it should be thought of as a system of components all designed to integrate completely into a building that would incorporate all of the necessary functions. The advantage comes from the fact that all parts--ceiling, walls, partitions and so forth--work together, and every component of our building will be called upon to perform more functions.

That was back in 1960. We had already started on some of this development work when my friend, Ezra Ehrenkrantz, your speaker of three weeks ago, pioneered the SDSC program, and, so naturally, we were interested in participating and working with him. We found our objectives were surprisingly parallel, and after years of effort and much expenditure, we submitted a bid. Unfortunately, we were second low in the structural and roof category, and hence lost this opportunity to the low bidder.

Because of the enthusiasm and interest evidenced by the SCSD evaluating group, plus the encouragement from Ezra, we chose to continue with the development and the commercialization of our product. Also we knew of many improvements and refinements which we could make in this, and about 12 months after the bid was opened, we introduced nationwide our comprehensive building system which we call space grid, a trademark name.

We are now marketing this product at figures comparable to our SCSD bid, and today we have constructed over one million feet of space grid and have about an equal amount of orders yet to accomplish. Our decision to continue has been validated both by our modest progress to date and by the fact that the SCSD low bidder in the structural category has apparently learned they cannot produce and erect their system at competitive figures.

So, it is from this background that I speak to you about building systems in the future, as I see them. I think the Boston Architectural Center is to be complimented on promoting this series of lectures as I am a believer that the best answers come through a thorough massaging of a particular decision, discussing all sides both good and bad.

Systems is the hottest subject in construction today, because it is the most revolutionary approach attempted to date to knot this fragmented industry together. Article after article has been written during the last couple of years, and entire sections of magazines and complete books have been devoted to this subject.

There are open systems, closed systems, sub-systems, total systems, comprehensive systems, systems approach, and so forth, all applying to construction. In fact, I paid my bill to Hertz Rent-A-Car the other day and I notice I made it out to Hertz Systems.

Systems programs similar to SCSD have been or are now being considered in Illinois, New York, Nevada, Florida, Pennsylvania, Georgia, Indiana, and Toronto, and Montreal as well. I am sure your firm is engaged in systems building. Even the Federal Government is getting into the act through the Bureau of Applied Technology. The Government Agency, HUD, is studying systems, and I understand the Catholic Church is also studying and considering the use of building systems approach to structures.

Even though the use of the word "systems" is being abused, thus adding to the confusion, I know of no better word to describe what is happening to construction today.

For the first time, other than at an architectural level, fabricators, contractors, engineers and the ultimate consumer are no longer looking at individual components of construction, but instead they are looking at the entire various planes of construction which in my terminology I will call sub-systems. You are beginning to see pre-planned integration of components all purchased from one source, and all working together for economy and improved function of that particular plane of construction. A good example of this is in the ceiling plane of construction where more and more you see the use of the entire pre-planned ceiling, not just the acoustical tiles, but the entire plane of construction; including the tiles, the lighting, and the entire air distribution system. And there are choices to fit your pocketbook and your client's needs.

There is one responsibility. You know who to blame. The joints are no longer no man's land, and, of course, the joint at the ceiling in the wall still remains the fault of the poor general contractor, unless, of course, you bought a complete building system wherein the vertical planes, the walls, are all pre-planned to go with the complete building shell. Then you have the manufacturer to blame for that joint and all the other joints of the material furnished by that manufacturer.

Architects and engineers have been putting building systems together for centuries, because any completed building is a building system of some sort. The difference today is that the pre-planned integration of the various components of construction is now starting at the industry level, causing system construction to be referred to as industrialization of construction.

To me, a comprehensive building system is going to be one that starts at the industry level with, first, a careful study of the function the building is to serve, and, then, a pre-planned integration at the product design level of the various components that make up the system; such as the structures, the roof, the wall, the wall accessories, the heating, air conditioning, ceiling, lighting, partitioning, and so forth; all to best accomplish

a predictable end result. All parts to be coordinated functionally and aesthetically into a whole system of components, compatible components hopefully with one component making the other more effective.

For a successful system, these parts must have flexibility, so that they can be repeated in use with value and economy resulting. If properly done, this results not in a standard building, but instead in building standards. To some extent the pre-engineered building industry has pioneered this trend. Admittedly in the past this development was in many ways arbitrary and without proper regard to the total need of those that it was going to serve; for years we pre-planned the various planes of construction all to go together, resulting in a building that has value with regard to speed of construction and economy along with many advantages for the user. However, this certainly has not been a comprehensive building system, because all that is included is the structural system--the walls, the plane of construction, and the roof plane. The industry combined these three sub-systems and offered choices to fit the client's pocketbook, depending upon the function that the building was to perform.

Because of the advantages offered, this industry has been growing at over twice the rate of the general components type of construction in the market served. When the SCSD system program came along, this gave us the opportunity to start pre-planning for heating, air conditioning, ceiling, lighting, and partitions, which now was beginning to approach a comprehensive building system. It has been said that the construction industry is the one major industry that has benefitted the least from science and technological innovations, and, to some extent, this is true. The primary reason for this is that the construction industry is so complicated and fragmented and tradition-bound.

Even today most products of construction are made by companies that make components only--structural steel, heating, and/or air conditioning; items such as windows or doors or brick or roofing and so forth. Up to now only the members of the pre-engineered metal building and the prefabricated home industry approached the offering of a complete building, and even now this is quite often just the shell.

The first conscious effort of comprehensive building started in England in 1946 and was successful to a sufficient degree so that in 1949 the Minister of Education began to assist in the spread of this concept of construction. Their approach, and it was started by the architectural profession, was to form a consortium, a cooperative group. They originally sponsored four separate systems with the belief that there would be a market of about 14 million dollars of construction for each system.

Some European systems have steel as their basic material, some concrete, and some wood, and several utilize a combination of all three. Since this beginning, there has been much controversy, and the concept has certainly had its ups and downs. Several selected systems have been unsatisfactory. Several companies have gone bankrupt. Certain elements of the construction industry have resisted it, but in spite of these difficult adversities, starting about 1958, the systems concept has been growing steadily. I am sure you are all familiar with the CLASP or the Brookhouse system in England, and it has been a most successful system.

Finally, after ten years of development, approximately 50 million dollars of construction was accomplished in 1967 with the CLASP system. They are far ahead of us in systems in both England and Europe. Last year over 20 percent of all school building construction in England was of the systems concept. CLASP particularly has branched out in end uses, and in 1967 offices, railroad stations, churches, hospitals, and libraries number among its many users.

There are industrial controversies primarily because most of the successful systems developed are closed systems which I think is a natural and unavoidable development. Nevertheless, there is no longer any doubt as to its acceptance, because of the economy both in labor and material--an average of 15 percent savings or better. Construction time has been reduced by an average of one-third, and there has been flexibility and excellent appearance with variety. In fact, several schools using the systems concept over there have received architectural awards. For the entire CLASP story, if you really want to learn systems, I suggest you obtain and read the Ministry of Education Bulletin Number 19 which is published by Her Majesty's Stationery Office in London. It is a very interesting document on systems.

Ehrenkrantz again as an architect was in England between '54 and '56 as a Fullbright fellow and studied this revolution in construction, and he adapted his SCSD program to what he learned over there. One notable difference was that in SCSD, American industry, the bidders (both the winners and the losers) paid the development tab; whereas, in England, the Government picked up the development expense, and is still picking up the development expense on systems development. This, like the SCSD program in the States, did accomplish two things. First, it started the architect, the engineer and the construction industry all working and thinking together on the pre-planning of a complete building, which resulted in the development of new construction products not previously available. And, second, it furthered the cause for performance specifications. I think the SCSD performance specification is a classic, and everyone knows that the accomplishment of this required dedicated effort and many long hours, but it demonstrated more forcibly than ever that a performance specification is an excellent approach.

I think an analogy can be drawn on the auto industry to demonstrate what could happen to the construction industry here. When industrialization came to transportation, at first it didn't include the appearance element too much. And it scared the hell out of its principal competitor, the horse.

Not much thought was put into comfort and interior environmental conditions in the early models. This mode of transportation has developed over the 50 years or so it has been with us, and we now have comfort, air conditioning, heating, and so forth, and the manufacturer has more and more controlled components that go into this system of construction.

In the beginning the manufacturer bought the various components that went into the car from others; some to his own specifications and some that were simply already being made, and by coincidence he could use them just as they were made.

Now, throughout this development there still remains other means of transportation, such as the airplane, the train, the bicycle, the God-given method, and yes, there is even still the horse around.

I wonder if as industrialization continues to come to construction, about the same thing won't happen? There will be complete systems that will compete one with the other, like General Motors and Ford. It will come in different sizes, colors, prices and will accomplish different end purposes according to your client's needs. The warehouse system is a truck and the high-prestige building system for offices, banks and so forth is maybe the luxury car.

As in transportation, the building systems concept will not be the only way to create controlled space environments which, put quite simply, is the only basic purpose of a building. The development of a total building system by industry is indeed a large undertaking. It takes many months of effort by a sizable group of people and,consequently, costs a considerable sum of money No single organization has today within itself all the know-how and experience and talent required. We had invested well over $300,000 at the bidding point of SCSD, and we had engaged much outside help. Without SCSD I doubt that any one company could have secured the needed cooperation from the other companies, unless it was accomplished by a merger of four or five companies similar to what is now called the United States conglomerate corporations.

The successful building systems, and as I previously indicated, there will be several, will take more than just combining presently available construction components into a pre-planned system; this was tried by two individuals who worked on the SCSD program and who later formed a company, designed a system using available components and sold one job, which "Engineering News Record" wrote up rather favorably in September of 1965. This company is no longer in business, and many companies learned from the England experience and, incidentally, several to date from the SCSD experience. It isn't difficult to get into business and fail.

We learned this in our Boulevard Home business. The true test does not come from any one job or any one big award in our free enterprise system. You simply pay your money and take your chances on your judgment, and this is the way I like it. After our organization's decision to continue with the development and the commercialization of the space grid, we contacted the other companies we had been working with in the SCSD, such as United States Steel and Lenox Housing and Hauserman and Owens Corning and we concluded arrangements for continued cooperation. We also decided that we would widen the SCSD horizon and develop space grid for designed loading conditions to comply with the four basic building codes in the United States and not just in California.

We decided to adapt space grid for end uses other than schools, but similar in function--that is people-related functions, and let me explain that. We believe that the various functions which require a building can be grouped to some extent. Two basic groups to be sure, would be to house people and to house materials. There might be many sub-groupings within these two, but certainly there is some common element between a resident unit and a motel unit, as there is between a commercial office and a school--all people-related. And surely there are some common elements between a manufacturing plant and materials warehouse--materials related.

Now, obviously I am not talking shape or dimension which establishes appearance to a degree. Any comprehensive building system must be made of sub-systems that are flexible as to dimensions, loadings, and appearance; all with the common denominator of a compatible system. Herein lies the strength of a good system which permits flexibility not only in the initial use planning stage, but also flexibility in changes of use and changes in appearance.

Pre-planning of all of the elements of a comprehensive building system can accomplish this to a great degree without sacrifice of economy. Certainly there must be some limitations, but with careful development these limitations can actually become strengths instead of weaknesses. Now, this does require an educational program, because many of us have used individual construction components so long and we have become so well acquainted with their use, that we have accepted their limitations and, you know, really we are no longer aware of those limitations.

For the further development of space grid we first established the objectives of our new building systems and we appointed the task force that met every two weeks during the 16-month development period. The task force had a key man, a man from products engineering, one from materials engineering, from financing, marketing, a consulting engineer and a consulting mechanical engineer. This group along with help from many cooperative companies carried the project forward.

The entire project as originally envisioned is still not complete, and while the make-up of this task force has changed some since the original pilot models and market testing stage in 1965, they still have periodic meetings and changes are continually being made, new outside suppliers added and new materials used. And this is certain to continue for a number of years ahead. Incidentally, space grid is a registered trademark and owned by our company

During this 16-month development period after the SCSD bid opened, we constructed a pilot model at our Kansas City Plant, and this is probably the most tested building in the world. This building was divided into three rooms. We maintained different heating and air conditioning temperatures along with the humidity conditions in each room, varying these on occasions to check performance, and we used the first Lenox DMS unit which was the heating-air conditioning unit winner on the SCSD to produce these conditions. We were fortunate to have a very severe winter during this period and, as you know, our summers are almost always fairly warm in Kansas City, so it was a good test.

This isn't a pretty building. It wasn't built for looks. We used seven different types of walls, three different overhangs, three different facias and three different ceilings, each with different lighting requirements. In short, we tested for the first time the predictability of performance of many components all acting in combination one with the other. Every construction system has a distinct something or several somethings that perform or function better than a

comparable construction component available. If you don't have that, you forget the whole thing. It needs to have flexibility with value, so that it may be mass-produced with economy.

Our system allows the architect the freedom of design in appearance, shape, aesthetics and roof levels so that he can use his best judgment in adopting our space grid system in construction of that particular end function. The architect can use traditional wall materials as he normally does, or select from any one of the seven different wall systems we have, depending on the function and the aesthetics desired.

In the past, the pre-engineered metal building industry has not been noted for working with the architects. That is probably an understatement. The industry recognized this need about five years ago and we are making some progress. From statistics gathered from the metal building manufacturing association in 1967, there was $22 million of construction utilizing the pre-engineered industry's products on architecturally-controlled jobs. Five years ago when we took a measurement at that point, too, it was much, much less. So, progress is being made by both parties. My company has been a party to furthering this trend by requiring that a registered architect or registered engineer be directly associated with each space grid project planned and consummated. Today we have over a million feet of square feet of space grid and an equal amount on order. This was a larger amount than accomplished in SCSD.

The systems concept has too many advantages and, accordingly, it is moving too fast to stop. Modern industrial techniques along with the computers will further accelerate this trend. Properly programmed computers can prepare a complete bill of materials of known systems and at the same time prepare estimated costs of both materials and labor both in shop and in the field; can schedule sequence and work to be done and so forth.

Our industry is already using computers to do this. Along with our planning of the inventory needs and reducing the inventory as it is called for and shipped, the ever increasing design and build concept was brought about as a method to shorten construction time from point of decision to point of occupance.

Systems construction will make design and building more effective and practical and will foster the team approach to construction projects. It will never be the only available way to build, but its share will increase tremendously within the short period of the next ten years, and it will probably level off growing as construction grows. I believe it is going to provide that technological breakthrough in construction that is so badly needed. It is predicted that by the year 2000 America will contain nearly 400 million people; that is about twice what we have now, and all these people will need buildings to live in, to shop in, to play in, and to work in. So, in the next 32 years we have to build as much as was built in the last 200 years.

During the last five years the value of architecturally controlled construction has grown approximately 50 percent, and it is anticipated that this trend will continue and even accelerate.

During this same period the trend in the number of architectural graduates has increased about 20 percent and I suspect that the proportion of those who will actually practice architecture has been declining. I also believe that it is an accepted fact that construction is becoming more complicated and that the same job requires more architectural attention today than ever before. It is, therefore, crystal clear that if architects are to continue to hold their present share of construction, they must find ways and procedures to accomplish this in the future. Systems offers them one solution. I see the architect and the engineer working even closer together; after all, the A.E. firm hardly existed ten years ago and is commonplace today. I see architects working for large construction and building systems firms and working less for a specific client on a specific project.

I am not one who believes that the integrity of an architect can only be preserved if he is paid directly by his client. Anymore than I believe that my child must directly pay his school teacher for a good education, or he must directly pay his doctor if he is going to get the proper medical attention.

Psychologically there is another reason why the system concept is certain to grow, and that is our inbred desire to accomplish things quicker. You know, as you travel around abroad a bit, you never see that worn path across the grass that we see in the States at the sidewalk corner. Now, I don't even know that it is good, but we Americans always want to get things, we want to get there quicker, and when we start building, we want to move in.

From a business standpoint there is a sound economical logical reason to move in as soon as possible. We want to move into that new house quickly and hope and pray that we can profitably sell the old one that has served us so well for the last 20 years. It is simply elementary that industrial construction with sections made in plants all preplanned to fit together and in the field will reduce time between decision and use. That has been one of the strengths of the metal building industry. Even more speed will be gained with modern equipment and new concrete materials, and time is even shortened on the site, as compared to ten years ago.

Systems construction will grow because this process honestly speeds construction time. The planning time before construction starts is greatly shortened. The system will be more economical, fewer people can handle more projects, and our vast building requirements demands will be met.

I think we will also learn that buildings are built to be changed, not built for 300 years of use, just as they are. As time passes new things must be done within a building and they can best be done in updated structures. Also, architectural styles are not only born, but they die, and the better systems of construction will plan for later changes both as to appearance and function.

Flexibility will be the key word. I believe industry will lead this trend now that the door has been opened by our progressive group of architectural planners and, accordingly, I believe we should look forward to closed systems being used more than open systems. Economically, it is to the client's benefit, and it is also to industry's advantage to do this, because we are all trying to enlarge our dollar volume, since our selling costs, a major item now and in the future, usually decrease in percentage as the

volume of the sale increases. It will surely cost more collectively for six companies to sell you six sub-systems--this being an open system--than for any one company offering a good closed system, a comprehensive building system. You say, I won't have the competition I want. Well, forget it. You will have plenty of choices in good closed systems and, really, under our free enterprise system, this competition is about the least of your worries.

Analyzing and choosing the best system for your client will be your problem, not competition. I remember one leading architect telling me a number of years ago that when our industry, the metal building industry, reached the point where he could specify the column and the strength of the roof beam, than I should come back into his office and he would make use of the pre-engineered metal buildings. For obvious reasons this has not come about, but I am happy to report that this leading architect is now using products from the pre-engineered industry. He does not always use the complete building--that is, the structure, the walls, and the roof--but instead he often uses the entire structural system, thinking of it as one component and, more often than not, he uses the metal roof as a second component.

Because of this, I see architects or A.E. firms not only becoming more knowledgeable about comprehensive building systems, but truly believing that one system has more value over another and using this system consistently for the end uses for which it was developed. More projects can be handled in the same amount of time, and more time can be devoted to the functional purposes of the structure and the space relationships as well as the broad, urban planning, and all that goes with this complicated function.

Mr. Charles M. Nes, Jr. was elected to the AIA presidency a few years ago, and he said, "Ultimately, the fragments of the building design team which today work together rather badly will probably cohese into one profession of environmental design. This new profession will comprise the design generalists, architectural specialists, interior designers, landscape specialists, engineering specialists--structural mechanical, and electrical engineers--and possibly the architect will be only a specialist under the design disciplines. We can't leap directly to a reform which probably will require 15 to 20 years of evolution. It will require plenty of friendly persuasion and diplomacy. You can't shove it down the throats of conservative architects and engineers. Personally, however, I welcome the prospect of becoming a part of one great profession, the specialist groups like those in the medical associations."

Bob Hastings has said this: "The architect of the future will devote more time to value judgment, proper use of space, total design concept; he will spend less time on technical and mechanical details. These will become the responsibility of the building component manufacturers who will become specialist experts in building systems and sub-systems. The manufacturer will develop, test, fabricate, install and guarantee the system."

Regarding housing in England, Mr. James Boynton, Parliamentary Secretary to the Minister of Public Buildings and Works, said thus: "Unfortunately, good ideas spread slowly and the Ministry are trying to vigorously persuade local authorities to industrialize their housing program and have builders cheapen the prices of their system. Some builders are apprehensive that they will be put out of business, and some counselors are afraid the industrialized system will spell their doom. None of these fears need be realized. The company requires all the builders it can get, and the industrialization of the buildings is completely the work of the builders, and good architecture and good living go hand in hand with the industrialized system."

Also in England they have learned that before you can use industrialized buildings, you must first industrialize your clients. The construction industry hopes that the architectural profession will help do this.

Bucky Fuller has said that the changes ahead of us are going to scare hell out of a lot of people. I suppose this is true, and I must admit that I, too, am somewhat scared, but I believe that as long as all of us keep our minds open to the fact that the only thing that is constant is change itself, and then try to fit our contributions into this vast fabric of construction, attempting in all sincerity to be a worthwhile and beneficial contributor, I bet we will pass on to the next world feeling that in some small way we did benefit mankind. Let's not be a part of the problem, let's be a part of the solution. Thank you.

QUESTION PERIOD

FROM THE FLOOR: What kind of finished roofing materials are you investigating?

MR. LARKIN: I am not going to evade any question that I can possibly answer. We are studying all of them--metal, Hyperlon--you think of it. As I have said, we do not even have two years of testing. I personally believe there is a better roof material than we are using today. I don't know what it is, but we are going to work on it. It is part of the sub-system. If I knew, I would tell you. If I knew, I would try to get your order, but I don't know. Yes, sir?

FROM THE FLOOR: Your constructions have been single-story so far from the slides I have seen. Have you experimented with multi-story structures?

MR. LARKIN: No, sir, we haven't yet reached that. It is in the development stage. It is contemplated. As I said, our space grid deal is an everdeveloping thing. It is in our program to develop two stories.

Incidentally, all of you should watch the development of this URBS program out in California. I don't know how much Ezra told you about it when he was here, but it is a very enlightened kind of a program. AISC have put together about $150,000 and Carig and Reed in California have developed a steel answer. Now, when the bids are open, nobody knows whether it is going to be steel, concrete, or wood, or what it is they have developed. It is a tubular answer; they are using the tubes for the ducts for hot and cold air, and those kinds of things, and it is a very interesting answer that they have come up with on steel. Whether it will win or not, I don't know.

FROM THE FLOOR: When you expanded the anticipated use to the space grid, did you do any additional performance specification type work?

MR. LARKIN: You are going to have to explain that to me, sir, I don't know.

FROM THE FLOOR: The performance specification was given to you by the California people for their school system, and using their specifications you developed a space grid. Then when you came in second low, you expanded the variety which you thought would utilize space grid. In doing this, did you look further into the performance requirements of these additional uses?

MR. LARKIN: To some extent. Not to the extent they did in California to schools. No, we did not, but having sold buildings throughout the United States for 50 years, we have got certain people, not all as old as I am, thank God, and we had some feel. Obviously, we had a feel of the companies. The biggest thing we did was to adapt space grid, and I don't want to talk seriously about space grid; I would like to talk about the whole building systems here.

FROM THE FLOOR: In regard to the space grid program, are you suggesting that a local architect be used for the building?

MR. LARKIN: Yes.

FROM THE FLOOR: With due respect to my fellow practitioners, I felt that your space grid examples were singularly sterile and lacking of any feeling of good design. Do you have a design review board at the factory, or is this a limitation of the system?

MR. LARKIN: Well, let's call it a limitation of the system, if you want to. It was pretty flexible in the appearance. You didn't like any of the appearances apparently, and that is your privilege. They were all designed by your fellow architects somewhere or other around the country, and that is the only way I can answer it. (Laughter.) We didn't design them.

FROM THE FLOOR: Do you have an architect on your staff for design review?

MR. LARKIN: We have three architects working in our engineering and development work.

FROM THE FLOOR: Would you care to say anything about planning grids?

MR. LARKIN: Well, any system space grid has a five-foot grid. Your California school has a five-foot grid, which is a limitation.

FROM THE FLOOR: Why the five-foot grid?

MR. LARKIN: Well, I wish Ezra had told you about this, because he would give you a long speech on why this is the people dimension.

FROM THE FLOOR: This is the what?

MR. LARKIN: A people's dimension.

FROM THE FLOOR: No, he gave an explanation of it as being a lighting tube dimension.

MR. LARKIN: A lighting tube dimension? Okay, I accept what you are saying. He also told me (and I have seen diagrams of people fitted into some of these things) that a five-foot is a people dimension, more of a people dimension than a four-foot, and a four-foot is a good lighting tube. There are damn few five-foot lighting tubes, but there are going to be more.

FROM THE FLOOR: The idea is that a four-foot tube fits into a five-foot grid.

MR. LARKIN: Okay, a five-foot tube in a four-foot. (Laughter) And because of the five-foot dimension you may now buy five-foot bulbs. You may know more about this than I do, and I am not saying you don't; all I am telling you is what I think I know about it. You may be right.

FROM THE FLOOR: Do you have any square-foot costs on some of these school buildings or per-pupil costs for the total structure and the site development?

MR. LARKIN: Yes, and they run all over the map. How long is a piece of string? You know what I mean by this. They are competitive. Now, I am telling you in all honesty I did not come here now to sell you space grid. I had to use space grid as an example of the system, and you can smile all you want to; I am not selling space grid now. I will come to each of your offices individually and talk about space grid, but here that is not the purpose, am I right?

CHAIRMAN MACOMBER: You are right, that is what I told you. (Laughter.)

FROM THE FLOOR: I couldn't follow you on the flexibility advantages of a closed system, in terms of choice, over an open system. I just can't see that.

MR. LARKIN: Obviously, you know what I mean by a closed system. Everything is pretty well spelled out. Sure, there is some flexibility in it. But the open system is taking it and calling it a sub-system--using the roof and the wall, and the one-roof system and the one-wall system and mixing it all up; and what I believe is this, that I can take and you can take, any open system and find a way to improve it on some element. Now, as soon as you do, you wrap that up in a closed system and you have a better system than that open system was. Did you follow me on that? In other words, I think if you wanted an open system with different kinds of walls or different kinds of this and that, that you can take a wall system, study it, and you can come up with a better system than that particular wall system.

You can take the weakest link of any complete building and work on that and you have a better building. That is what I mean, and I say industry will do that, and then I further say it is to the advantage of everybody to pick a closed system. I think this is going to be the evolution and I don't know how long it is going to be. Like I said, the automobile has been here 50 years; do you realize that? Systems haven't been here very long.

FROM THE FLOOR: You showed us a number of buildings and all of them were rectangular in shape; have you done anything in non-rectangular shapes?

MR. LARKIN: If I had shown you floor plans of some of those buildings, and that is how you see the shape, you would have seen a lot of wriggling around. That is the advantage of a flat roof, you can wriggle the walls all around, and there is a lot of wriggle of the walls on those illustrations you saw. I am sorry I didn't include that, particularly in the Fullman Standard Research job; hell, walls wriggle all along the thing inside and outside the grid.

FROM THE FLOOR: A less hostile question.

MR. LARKIN: You can't ask me a hostile question, I am not mad at anybody. (Laughter.)

FROM THE FLOOR: As you see the development of the systems, how

do you see the role of the architect with his present background, training, and experience and contribution to building as being a part of the systems development other than what Ezra is doing in California as a generator? Would you be willing to comment on how your firm looks toward the integration of the architectural profession in this?

MR. LARKIN: Well, I tried to indicate that. I don't know, but architects are not as flexible as they claim to be. Architects get to using something and they believe in all truthfulness this is the best. So, they use it. Now, I think the same thing is going to happen with respect to systems. No system is going to stand still, it is going to be improving all the time, and an architect is going to decide, this is the best system for this client's use, and you are going to use it, you are going to be acquainted with it, so you are going to use it a second and a third time.

I wish I knew a real answer on that, but I think that is what is going to happen as time goes on. Now, he will get mad and he will go to another system. He has his right to and all that, but maybe sometimes he will come back to the other system he got mad at, too. You all had experiences as practicing architects, I am sure, in this same kind of a free-for-all. There have got to be opportunities for innovations in any kind of a good closed system. Really, an architect is a good businessman, too, and he can do the second job better and quicker, and I believe this point solidly.

Now, if the architectural profession is going to hold this position in this broad construction field and in all solemnity I say I hope they do, because the better buildings that we have got around are ones that architects are connected with and they will sell more products, and I will put it on any basis you want to.

FROM THE FLOOR: You are not saying all the architects are being a part of the Butler Manufacturing Company in any major directive force.

MR. LARKIN: No, no. I see us using them more and more, and this has all come about in the last six years. I see us using them more and more in the product design, and some of these will be consulting architects. We are using them all the time, and we have three architects on our payroll. I know at least one of them is an AIA guy. I think that is all right. (Laughter.) They are helping us on the product concept, not on any particular end use, and that is okay too. Of course, our buildings are, and that is where the creation really happens down at that level.

FROM THE FLOOR: Do you have any industrial designers in your firm?

MR. LARKIN: Well, yes -- tell me what an industrial designer is? We have a man who calls himself an industrial designer. He has a diploma to that effect; his name is Bob Orr; he helps us on colors, and he is damn good. I didn't know it before, but there is a trend in colors, and you can lead the field too far and you can be back too far.

FROM THE FLOOR: You made reference to not wanting to build buildings used for 300 years, and that is an exaggeration, but what obsolescence age do you really want to be looking forward to? I mean, you are a manufacturer, like the automobile manufacturer, let us say, and what do you want to project what the life of a building is? In other words, when do you want to replace the one you have already built?

MR. LARKIN: Well, I can give you the United States income tax rule which says 40 years, you depreciate.

FROM THE FLOOR: Be honest, never mind that. (Laughter.)

MR. LARKIN: I am starting off on that. If you don't think I have been honest in everything I have tried to say, forgive me. I just started off saying that that is the first answer. I did not mean to imply that the whole building ought to be torn down. I believe you can design a building that you can change and keep its, let me call it, its skeleton, and I think as time goes on you are even going to be able to move some posts around which is usually the interior limitations, or get rid of posts entirely on some other kind of constructions we have. I don't know, I would say 40 years honestly. You show me a building -- no, no, now, I don't want to say that. (Laughter.)

I guess you can find me a building 40 years old that the architectural profession will look at and say, gee, that is good looking and that is still performing a good function. I think that is true. That is one of the nice things about the building in this profession, you can carve yourself out a real fine business for your life, and it ain't very long and you do pretty good; just a little bit of this business, and let's have variety.

Now, I don't know how to answer your question any better than that. You had something in mind. What was it? This is an open forum meeting; when you asked that question you had something in mind.

FROM THE FLOOR: You know the reputation that metal buildings have had. I mean, you faced it and you are certainly upgrading and coming around more to the conventional treatments and bringing other materials in besides your own metal, which to me is fine. You are coming of age. Before they were on tin lizzies.

MR. LARKIN: That is true.

FROM THE FLOOR: So, I didn't know whether you really felt you should still say, keep them almost as cheap as possible and let them fall apart and let's build another one--like the automobile industry which is accused of having a short-life planned obsolescence--and a good many of us are making quite a bit of altering buildings, and we are improving a good many of the ones originally built.

MR. LARKIN: And the easier you make it to make those changes, isn't that going to be a step towards progress?

FROM THE FLOOR: Yes. Incidentally, on that same score I would like to know what you are really doing about leakage.

MR. LARKIN: Roof leakage?

FROM THE FLOOR: All kinds. God knows it is a problem. When we get a storm like the other day, everybody is rushing for the buckets and pumps, and there aren't many buildings that survive, and metal buildings have always been a victim. I wonder what you are doing? There is something that has to be done by manufacturers like yourself.

MR. LARKIN: I always say we are the only ones who offer a 20-year guarantee in this metal roof industry.

FROM THE FLOOR: I am glad you said that.

MR. LARKIN: Well, it is worth something.

FROM THE FLOOR: Not with all the other manufacturers, it isn't. Ask these architects where they ever got with it.

FROM THE FLOOR: I just want to say if we are going to try to be objective and understand the import of what you say, and I am not an architect and therefore I am going to try to look at it a little differently--it seems that the future will mean that all the Chevrolets of the industry will be done by the prefabs or the metal industry, and the architects will be designing Cadillacs.

MR. LARKIN: No, I don't quite believe that. I know what you mean by Cadillacs, and there is a level of quality there, I think you mean. They both transport you. In fact, what do you mean? They both transport you. They are both automobiles. If I want to get from here to there, I can go there in either one. What is it? Prestige? Do you want to feel like you have got something that fewer people have?

FROM THE FLOOR: Again, I say I am not an architect, but future generations will look at the group of buildings you are talking about and have a different attitude toward them than toward the ones designed by the architects as such.

MR. LARKIN: Well, it isn't price now, if that is what you meant. It isn't what, glamour? You architects are driving past metal buildings of ours and other competitors and you don't see them any more as a metal building; you don't recognize them as that, because they don't have a name up there anymore. We have built buildings at $35 a square foot, and that is a pretty Cadillac. Any more questions:

FROM THE FLOOR: I think at this point I am a little disappointed in the line of questioning. I think we are involved in a changing society, and I would hate to have the impact of some of these slides that you showed us lost on the group because of some of the questions.

It sort of reminds me of the rayon industry. Rayon was a product that was a miserable failure for a long period of time, and then people said, what are we asking them to do? And they went along and really produced better rayon, and now it is used in the finest of fabrics. We have so many social situations in the country, in the world today which need better answers, and I would like you to make your point again about the need to open up and to be more creative.

MR. LARKIN: Well, it is the point of being open-minded on things. It is hard for all of us, I know, and I have my own selfish ideas, too. I don't know how to say it other than human beings resist change. But you have got to get used to change. Every one of us. And once you get comfortable with changes (and I think I am fairly comfortable with change, the only change I wouldn't like is for my wife to leave me.) (Laughter.))

You can have change without having any real fixation on something. I really can. But I am a long ways from being where I ought to be on it. I don't see how an architectural group can be anything but this--comfortable with change--and I would submit that you ought to be this way; you ought to work damn hard on it.

I don't say that anybody has got the best answer necessarily, but you have got to strive to find a better answer, and there is always a better answer.

FROM THE FLOOR: I get the feeling that there might be some confusion, and I think your identity, which is impossible for you to lose, might have tended to confuse some of the people.

The subject matter is not metal buildings; the subject matter is integrated systems or systems approach or as Wilbur has used, comprehensive systems, as a newer and, hopefully, a better approach to building solutions which will enable the architect in conjunction with the manufacturer to do a better job and to come up with better solutions to buildings in the future and leave the past where the past is.

Please don't allow yourselves to be confused. I think you will have missed the whole point of the series and the whole point of the lectures if you permit yourselves to be confused by the two concepts.

MR. LARKIN: I appreciate that, and in what has been known as the Butler Building, we don't have a building system. I said it was the start of it, and all we think we have in a space grid is a step toward that direction. I am glad you brought that point out.

THE ROLE OF STRUCTURAL DESIGN IN SYSTEMS ANALYSIS

WILLIAM J. LeMESSURIER

William J. LeMessurier is President of LeMessurier Associates, Inc. in Cambridge, Massachusetts, and Associate Professor of Structures in the Department of Architecture at the Massachusetts Institute of Technology. LeMessurier Associates have been structural engineers for many large projects including the new Boston City Hall, the State Street Bank and Trust and new First National Bank buildings in Boston, the entire new campus for the Rochester (N.Y.) Institute of Technology, the New Haven (Conn.) Arena, and the new system of Great High Schools for the City of Pittsburgh. LeMessurier is working with Ehrenkrantz and others on the team for the University of California Residence Building Systems Project. He is also on the Advisory Board for Hospital Construction for the Veterans Administration.

MR. LeMESSURIER: If you were to open up the Steel handbook, we might make an abstract of a few entries from an article called "Economy of Structural Shapes," You would find an entry that looked like this: 16 wide flange 40. That is a pretty good beam and it has a section modulus of 64.4. You would even find that listed in bold-faced type. Now, omitting some of the other sections in the list below it, you would find something called a 14 wide flange 43 with a section modulus of 62.7; a 12 wide flange 45 with 58.2, and finally in another bold-faced typed entry a 16 wide flange 36 with 56.3.

Now, I think practically everybody here has used the Steel handbook at one time, or they have learned to open up to this page and learned to find the bold-faced typed member.

Let's suppose we had a problem that was to select a beam whose section modulus required this-57. These are the bold-faced typed beams. What beam would you select? This beam doesn't have enough. This beam is the lightest beam of the group that does have enough, so you choose 16 wide flange 40.

Now, at that point you are being only a structural engineer. Let's say that you are a systems analyst. What do you do? First of all, if you were present at Ezra Ehrenkrantz's lecture here a couple of times ago, you would have heard him say that the space, that the sandwich that makes up the floor through to the ceiling, costs two cents a board foot. He didn't put it quite that way. He said that if you are going to design a system and you are going to reflect the effect that you have on selecting this beam on all the other elements of the building, you have got to charge yourself at least, say, for college dormitories, which he was talking about in his URBS program, two cents a square foot for each inch of depth.

So, now, let's take a look at our design problem. Supposing these beams are going into a floor system and they are being used at 10-foot centers. In order to decide what beam to use, you have to have some quantitative way of finding out the relationship of that decision to all the other aspects of the building.

Ezra Ehrenkrantz's two cents per board foot of space rule is a very helpful one and simplifies my example. We also have to decide what does an incremental pound of steel cost which is a different thing from a total pound of steel. If you design a steel building, you may guess the price at 18 cents a pound today, but it is a different matter to add pounds to a beam that you have already lifted, connected the cut, and so forth, and probably a better value for that is 10 cents a pound which will cover the raw material at the mill, the shipping and handling, and we will assume the connection costs are otherwise the same.

What does this beam that we have selected as being so economical cost us? Well, it weighs 40 pounds per foot. If we divide the weight by the spacing of 10 feet, we get four pounds per running per square foot. We multiply by 10 cents a pound and we find we have 40 cents for the steel; but now that beam has set a dimension in the building, and the space that the 16 inches requires is going to be required over the whole building. So, for every square foot we now have 16 board feet, and at two cents a piece costs 32 cents. So, we have 72 cents a square foot in order to use that beam.

This two cents, I am not going to try to go into detail of it, but the business, the exterior finish, the extra run of stairs, the extra finish that goes through the staircase and piping and so forth, this number has been carefully studied. I don't claim it is absolutely right, but the point is there is such a number that you have to know before you decide what beam to use. We go down the list and take the 14 wide flange 43 and, of course, that is going to cost 43 cents a square foot, but it is only going to take two times 14 or 28 cents for the space, which gives us 71 cents. We have already got a little improvement in cost there.

We finally go on to the 12 wide flange 45, and it is obvious that is going to cost 45 cents a square foot for the beam, but the space it takes is only going to cost 24 cents, and that is the best buy.

Now, the thing will work out differently if I space beams at 20-foot centers, if I space the beam at 10 foot, and this is the 10-foot centers, and if I space them at 20-foot centers. The relative costs are going to become 52 cents, 49 and one-half, 46 and one-half. The bargain for the 12-inch beam becomes even more advantageous.

If you put the beams at five on center, it will come out the other way. Finally, the 16-inch beam will become the economical beam if you have them five feet on center. The point of this demonstration is to give you a feel for a systems analysis problem. You cannot design a structure by itself in its own terms.

Let me just elaborate on that point a little bit. Why don't we do this? Why haven't we been doing it? Why isn't the structural engineer thinking in these terms?

Each of us is evaluated in terms of his own performance. If structural engineer X takes four pounds of steel per square foot to build a floor and structural engineer Y takes four and one-half pounds, who do you think gets rehired by the sophisticated owner? Engineer X does because the owner looks at the engineer's performance -- how many pounds per square foot did he take to build that last building? The owner has no way of evaluating that engineer as a member of a team. Unfortunately, I think we engineers design to minimize the cost of our structure rather than the cost of the building.

Now, let's leave that example and be a bit more general. I will try to outline a building system, give some examples, and then discuss how building systems evolve. At the end of this evening I will give you a personal example of a case history of a building system that I am involved in creating as a member of the team.

A simple example of a building system might be the set of Lincoln Logs that many of us played with as children. Within it are many of the characteristics of a good building system. Lincoln Logs have, first of all, a conceptual idea, which the user, the builder, can understand. It has some dimensional standardization. It has a method of making joints. They are made of a material which is cheap, widely available, and have some degree of flexibility in organizing building configuration.

Point number one of a building system: A good building system is one that has a relationship to its time and place. Point number two: It has some degree of dimensional standardization. Point number three: It has an idea for making joints.

We have to have an established relationship with sub-systems and, in terms of buildings, this means an established relationship with mechanical electrical systems, adaptability to various plans; and above all, universal understanding by designer and builder. All of these points might be better made in the phrase by the philosopher of systems, Christopher Alexander, who says a building system is a kit of parts and a book of rules. It is not just one or the other; a kit of parts involves and implies a decided kind of geometry. It implies decisions about quantitative relationships. A book of rules implies some kind of order.

In addition to being a kit of parts and a book of rules, a system must be created. Perhaps the most powerful creator of building systems is evolution.

Many building systems exist around us which we have never thought of in these terms, because they are so familiar, and because they are so perfect. An example is the Eskimo building an igloo. At one time, the Eskimo was faced with, first of all, a need for building something. He fashioned himself a tool. The material (well-packed snow) was available. He had a conceptual idea of a geometry with some degree of modularity, and he knew what to do. He cut some snow in blocks, fitted them together, and he had a house. The house had a relationship to its place and time, availability of the material, some degree of dimensional standardization, and an idea of how things went together. There was universal understanding by designer and builder.

A more sophisticated example is the wood frame construction of America. People coming to this country brought with them a kind of crude framing tradition from Europe, and with a tremendous supply of lumber and the invention of sawmills and railroads, we evolved in a rather short time a system which we now understand and practically everybody in the country understands. We have two-by-fours and they are at 16 inches on center and we know how to make the joint when you come to the corner. We not only make that joint so that the structure works, but we make it so that the plaster can be nailed on from the inside and the clapboards from the outside. The space created by the joints solves the insulation problem. The over-sized studs evolved when it was discovered that you needed to cut holes in those joists or studs so that you can run the pipes and the wires around.

Our industry has adopted this system. You can look in the Sweet's catalogue and you can find dividing doors, and they will be dimensioned to fit three and five-eights plus three and three-quarters-inch sheeting on the outside. The four-by-eight plywood sheet or plasterboard, is related to the 16 inches on center, which everybody knows is to be used.

When the manufacturer wants to make a medicine cabinet, he knows there is going to be a space at least three and five-eights inches deep in which he can put it. He doesn't have to talk to anybody about that, he just knows that it is going to be there, unless some fool is going to build out of some other system.

Running the wiring, you can design a heating system, because you know exactly where it is going to go.

People have thought about better ways of building houses, and over and over again they come up with the fact that there isn't a better way. Every time they invent a new way, they find that they have left something out that the evolutionary process has already considered.

It seems that the systems designer whom we have to match with our skills is this evolutionary process. There are other examples. In a relatively few years since the war we have invented building high-rise apartment buildings. It also started out with a kind of structural idea, the flat plate. But this is a disarmingly simple thing which particularly satisfies this requirement of adaptability to various planes.

Going back to the wood frame for a moment, it is remarkable that Royal Barry Wills was able to build all his houses out of that system; and Walter Gropius, when he came to the United States, was immediately able to build all his houses out of the same system, and that the same system worked for both. This was a remarkable degree of adaptability.

The flat plate department also has adaptability. By putting it all in one solid slab, you have the freedom of putting holes in relatively freely, putting columns where you want and getting the thinnest dimensions. The mechanical system for apartment buildings relates directly,

as they require vertical passage; and flat plate apartment buildings have swept the country.

We could pursue these lines which I won't do. I think there is an equal building system which is kind of understood and not talked about in the steel frame office building and so forth. These are evolutionary systems.

There is another way to design or create building systems. That method is to say I have it, I look at my problem, I as an individual sit down and make a study of the problem. I say to myself that I can create, as an individual on paper right now in this particular limited design problem for this particular client, a system which will work. Many of you do this daily and have been doing it throughout the history of architecture. This is the difficult method and probably the most common.

I would say of the Boston City Hall that here was an attempt within one building to solve all the problems that are on this list -- creating a way for organizing a building which is new, better related to the time and place, built out of available materials, and with dimensional standardization in order to put the thing together. Obviously the system is adaptable. But I think you are asking yourselves to do too much when you are trying to create a new system for one building.

Is there a better way to design a building system? There is, I think, a development going on of a different way of approaching the design problem in relation to buildings, which you might call systems analysis. The first thing you have to do when you design a building system is to consider the user needs. From these you have to develop some quantitative criteria, the development and testing of trial design solutions; plus the question of economic relations. Each user need is an entirely new problem and because it is new, you will pay very careful attention to it. Once the need is defined half the battle of systems analysis is accomplished. User needs are defined by establishing the reason for the structure. This is the first step and I cannot overemphasize it. It changes your whole attitude about what a building is and what the spaces in it are like and what it must do for you.

In every hotel they have modernized the bathroom and they have put in beautiful tile and put in the sliding doors in the shower and they have a scale to weight you and a box of Kleenex, but when you try to shave in the morning, there is always a shadow under your chin because nobody has asked, what do you do in that bathroom? They haven't put the light in the right place. The light doesn't get underneath. This is such a simple thing, if only Mr. Hilton knew.

From the user needs, the designer establishes quantitative criteria. An example of the quantitative criteria is a determination of a module. Once you have decided that, you can then start relating all the subsystems of the building together. So, this is really a very practical kind of tool. If you have a good set of user needs quantified and to some established criteria, you arrive at the third stage -- the development of true design solutions. At this point you resort to brainstorming sessions, but with these guides behind you.

I work with a wonderful team at M.I.T., developing a kind of a building system for apartments. We worked very hard, particularly on some of these quantitative criteria. We really didn't have such a grandiose job of the redesigning of the whole method for housing, but we did have a method to try to use steel better in buildings.

We defined it in tall buildings. Our problem is to build a tall building and build it so the floor thicknesses are not so great, so that we could compete with the flat plate which is what the steel plate industry wanted us to do in the first place. Narrowing this problem down in that way, we then said to ourselves, one way to get an efficient building that is tall and resists the wind is to put all the columns on the outside. We did this, and then we linked them together with some trusses, and then pushed the trusses around to get the spaces, so that the building could work, and we got this thing called the staggered truss system. People wondered, how did you ever get that idea -- why didn't anybody ever think of it before? And the reason is that nobody ever asked that question in the homework in the first two stages. The fifth stage is to test it against these quantitative criteria, and you do this objectively and this is a little bit difficult because if the guy who comes up with the idea is also the guy testing against the criteria, he can also cheat on himself.

Once you have a scheme, you then try to search out carefully within that scheme what parts are related to one another and affect one another in a cost sense -- using cost as the common denominator. From this you may modify the scheme.

Cost optimization is really an extension of testing against quantitative criteria. Take for example, this construction purchase matter. Ideally you have a big market for whatever you are doing in the first place, because if you don't, nobody is going to get interested in helping you, and if you go out with a design for a new bathtub which has a perfect slope at the back and a rim around it that is self-cleaning and is the perfect thing, you won't be able to buy it unless you can order a hundred thousand of them.

You have to get yourself into the position to be able to attract the constructor.

I will tell you how an actual building systems design problem is progressing that is not yet complete. The City of Pittsburgh is very much like the City of Boston. It has a lot of schools. It has somewhat larger ghettos than Boston. It probably has the same kind of problem of being hemmed in by its own suburbs. It has a few things that are different -- one of them being a very powerful group of concerned citizens who may live in the suburbs, but are genuinely active in the affairs of the city. The city conceived the idea of taking a very bold step to help people who live in the city by rebuilding their educational plant, changing the quality of the education that went on in that plant, hopefully to the point where it would be so good that it might even attract people back to the city.

So, they engaged sociologists and educational consultants and considered their own user needs. A grand program for defining these needs and the direction for their solution came out which involved the rebuilding of all the schools in the whole city and a change in the whole quality of education.

The plan is to build five new high schools to replace 17 old ones. Each high school must be able to not only educate the 8th through 12th grade, but become a kind of community center.

It must be operable year-around, must be available to adult education programs of all kinds, must relate to the transportation system in the city which will also get reorganized, and will do some important things in bridging gaps between neighborhoods and, in effect, restructuring the city.

At this point, the city engaged simultaneously Ezra Ehrenkrantz's firm, Building Systems Development, who were charged with the problem of looking at all these user needs and defining in these quantitative terms the lines for design.

On the other hand, they engaged an architect to organize the team of designers for five schools of approximately a million square feet each, to be built simultaneously. This was rather remarkable, because the city itself set up all of the necessary conditions for the first few stages. They investigated their own user requirements. They established the team to set the criteria, and then they chose another team to do steps three, four and so forth. I have been privileged to join this team, entering the scene when the architect, the mechanical engineer, the electrical engineer, and associate architects from the City of Pittsburgh all met to discuss their user requirements, plus the quantitative criteria.

I am not going to go into detail on these quantitative criteria, as this would require documentation, and the development of the criteria is still going on.

This team has worked together since last spring, and this has been one of the more satisfying experiences in my life, because by having set the problem carefully, each person, whether he be the electrical man, the laboratory consultant, the kitchen man or the structural engineer, can grasp the whole problem, because he is exposed to the whole problem.

The architect as such has an unusual role, because there is one architect who is the form giver -- Mr. Obata in this case -- because he has a very strong personality, because he is able to withdraw without having to sit around fulminating all day. Then there is another architect with whom he works, and it is not Ezra Ehrenkrantz personally, it is a partner, Christopher Arnold, who is constantly there keeping track of everything, and if somebody gets too formalistic at any one point, he draws you in and back and so forth.

So we are all liberated. We have all gotten to know each other very well. As a matter of fact, we have gotten along so well that one of the team gave us all sweaters for Christmas with the initials, Great High Schools on them. (Laughter.) We have to wear those at our meetings.

As you can well imagine, a high school is a very complicated structure. It includes a theater, a gymnasium, offices, classrooms, and places for people to relax and be comfortable; so that every aspect of our life gets involved in a high school.

We have applied great effort to design space which is flexible for use in the traditional kind of teaching. But the teaching space is not traditional. From the very beginning it was understood that educational philosophy is changing all the time. At any one point in time there are several different points of view as to the organization of a school. Some people want little groups, some big groups, some like the classrooms the way we have them. But one thing you can be certain of is that no one knows what the truth is, so that among the requirements for the building, the ability to change, was the most important one. This lead to the idea of building fairly large blocks of space, and we began to think in terms of dimensions of 100 and 150 or 150 by 150. But, an area this large is impossible to span. Finally through discussion you begin to understand each other and start putting a few columns in this kind of a space.

This is a big problem. It is harder than the office building when you consider this much space connected without a core. It is only fed with air from the perimeter. You have bigger ducts in there than you do when you have air coming out of a core. The buildings are more like office buildings than anything else, because of the requirement of rather precise control, and the condition of spaces from an air conditioning point of view. The structural engineers enjoy thinking in their own terms, and after working, you and the architect realize all the spans need not be the same. Out of this requirement for a lot of duct space, requirement for a long span, the structural engineer wants to get a bit of an efficient structure, the mechanical engineers want to get a lot of duct space, and the architects want to have something in the way of an articulated ceiling.

I decided from my point of view to go back to the old-fashioned way as the trial design and optimize my problem in my own terms. What is the structure I would like to build here? This is the brainstorming session. It is flat at the bottom which the architect wants in order to put up partitions. He does not want articulation up and down from a plane on the bottom, so that is all right. There is a lot of space, room for duct work. By placing columns it begins to take shape. The remaining problem is how to put the floor up here. Suppose this is the main girder system 40-60-40. You create a space which is 60 by any dimension. There is no need to have anything big from the other span. So, I can put some beams in and put them down at the bottom of this system, trying to satisfy that criteria flush at the bottom.

Now, I have to figure some way to put struts in to hold up the floor. This scheme has survived all the tests and as it has been worked on these beams with the little posts holding up the floor have merged into kind of funny trusses in steel and other kinds of things in concrete.

The lighting engineer suggested putting a ceiling there, and then I put my lights down here, and then I can get that perfect kind of lighting which is indirect, because I can bounce off the ceiling and yet the lights are contained within this dimension because the beams have been dropped down. The ceiling will clean up some of this duct space up there, so I will have a ceiling and I can satisfy the problem of acoustic isolation when I put my partitions underneath.

The mechanical man is delighted with all this space up here. The structural man is delighted because he has a five-foot deep system to go 60 feet, so he can put his post tensioning and get the perfect grade across here.

Well, this sort of thing has evolved and it is still evolving. I don't mean to present this as a finished solution. I

am trying to give you a little flavor of the kind of things that go on in such a discussion. You get a little bit dizzy when you work on these things and you have a tendency to lose your grip -- a sort of euphoria that you have got something wonderful. Therefore, an important member of the team who draws up this is someone who is remembering the reality of the cost and the ability to make this, and we do have one of the large contracting firms, the Fuller Company, who has a team of people who are full-time set up to do all the administration of predicting cost and gathering up sub-contractors around the country and trying to evaluate what we are doing. As we get feedback from this, of course, we have to go back and redesign. That indirect lighting system, for example, turned out to be rather expensive -- not in the structure, but in the lighting itself.

On the other hand, we tried to develop a continuous working relationship with the manufacturers as a means of keeping in touch with reality. One man suggested that we had too many pieces in this system. He would produce something that spans not 40 feet, 60 feet, and 40 feet; but would span in the other direction and eliminate all those girders. One of the nice things about a project of this sort is that if you can develop a working relationship with industry, they can give you some new input.

A final point before I show you the slides. The scale of this project makes it possible to do some rather interesting things in terms of buying. It is our intention say, in floor beams (of which we may need 20,000) to go to bid on pieces and parts before the buildings individually are all put together, saying to a supplier, here is what we need. We need the first 4,000 to start delivery one year from now and then to keep coming at six-month intervals. This kind of changes all the rules.

If you add those beams to some stair panels and some girders and other things, you can go into the pre-cast business and go out of it again when the project is over, and hope for some unusual response.

This project is approximately seven times as big as the University of California residence systems that Ezra Ehrenkrantz told you about before. It represents in one package all the buildings that have ever been built out of the British system called CLASP.

(In this final portion, Mr. LeMessurier showed some slides of the high schools designed for the City of Pittsburgh High School Project.)

QUESTION PERIOD

FROM THE FLOOR: From a public area I was interested in this team where the contractor joined with the team; does that mean that he has, or will get the construction, or will it go out to bid?

MR. LeMESSURIER: No, he does not have the construction. Whether he has sacrificed his ability to build or not, I don't know. It is conceivable that he might be given a contract for management in which case he would be asked to sub-contract everything, but he is being paid for his services as a construction consultant and, of course, is a valuable member of the team in this kind of a system.

FROM THE FLOOR: How do you tactfully get the user to really look at his needs?

MR. LeMESSURIER: I am not sure I can answer that question. It may be the user can't himself. I think there is perhaps a skill in looking at user needs without even disturbing the user. This is, I think, the hardest part of the problem, and it is the one that we perhaps think about the least.

FROM THE FLOOR: Is cost or budget a factor in the analysis?

MR. LeMESSURIER: I think cost is always the factor. It is the factor in the end. It is the way we relate the possibilities and make choices.

FROM THE FLOOR: I mean, are you aiming at a cost per pupil or cost per square foot or total overall budget, or how is cost woven into this final cost?

MR. LeMESSURIER: Well, a great deal of effort is being made trying to relate maintenance changeability, putting values on changeability and talking about long-term costs rather than initial costs.

Initial cost is, of course, being looked at. It must be. You have to finance the project. At the present stage initial costs look very good. We are involved here in a very large school in Massachusetts which was designed more traditionally. The cost including all this air conditioning and lighting and so forth appears to be perhaps ten percent more than the ordinary, but it has a tremendous amount of flexibility, and it has already been found highly acceptable to the city -- more than was hoped when they started out five years ago. Instead of 125 million, you can about double that for the five schools and all the attendant costs.

FROM THE FLOOR: Bill, you have been working on this rather gigantic program which is $250 million or so, but do you have any feel for how small a project or program would be feasible to handle in a similar manner? What scale are you talking -- a $100 million program as a reasonable cut-off point or a $50 million program, or is there any minimum size to which the application of a complete and fresh approach could be detailed?

MR. LeMESSURIER: We talked about a number of things tonight. Systems analysis which is different from building systems can go on at any level, but the smaller the level, probably the easier. This ability to create and use a set of parts probably has to occur at a fairly large scale.

I have been an advisor to Ezra Ehrenkrantz's team at the University of California and had a chance to see the submissions a few weeks ago, which I can't talk about till June, but it is probably true that the University of California's program was not really big enough with a range of 4500 to 9000 students at say $ 6000 a piece; the plumbing people, for example, said the number of bathtubs for this project is three hours of production in the plumbing industry, and we are not going to re-tool.

The funny thing is, however, that when you create the situation with enough eclat so that everybody gets interested in it; the plumbing industry is producing a new bathtub because they see that there is more to this project than just a market for that project. So, the results are taking place even on something which is from a purely local point of view, not big enough.

FROM THE FLOOR: What was the reaction of the people in Pittsburgh of going into it with concrete in a steel center?

MR. LeMESSURIER: We haven't even decided that. In fact, we may well go to bid with both systems, which seems to be the way to resolve the problem.

FROM THE FLOOR: Don't you think there would be local pressure?

MR. LeMESSURIER: Of course there is local pressure. The funny thing is, if you made the decision to go pre-cast concrete, the pre-cast concrete man may say, all right, I have the job, now my price is going up. The same may happen with the steel industry, too. It is my feeling we better keep the thing open if we are going to buy the schools at the lowest cost to the city.

FROM THE FLOOR: Do you think you would consider wood?

MR. LeMESSURIER: It is possible. In fact, we had open meetings and invited manufacturers from all over the country to come. It was brought out that there might be a market, quite a market for wood in say the gymnasia, and if M.I.T. could build it, why couldn't Pittsburgh?

FROM THE FLOOR: Have you considered re-evaluating your engineering fees on a board foot basis? (Laughter.)

MR. LeMESSURIER: I re-evaluate my engineering fee every month, but I haven't come up with a good one yet.

THE ANATOMY OF A BUILDING SYSTEM

MOSHE SAFDIE

Moshe Safdie was born in Haifa, Israel. He is best known for his design of HABITAT at EXPO '67 in Montreal which was one of the first and best-known examples of utilizing prefabricated concrete space modules in systematized construction to have actually been realized.

Before going into private practice, Safdie worked for Ginkel Associates in Montreal and Louis I. Kahn in Philadelphia. Among other projects, he is currently working on "Habitat Puerto Rico," a low and middle-income housing project; "Habitat New York," upper-middle and luxury housing, and the Student Union at San Francisco State College.

MR. SAFDIE: I think it is important to first qualify what we actually mean by building systems and to me building systems means three things in one:

Building systems are an approach or an attitude to the technical method of construction. It is a systemizing of the process of construction.

Building systems are also environmental systems, considering the urban environment as a system.

Finally, building systems could be thought of as an attitude or an approach to the design process itself, and that again is different from considering building systems as a construction process. Rather it is a distinct attitude as to how a building gets the form that it ends up having once it is built.

I would like to discuss the three aspects which are one thing.

The fact that we talk about building systems in the first place has to do with the reality that many forces are acting upon us as designers, as builders, as engineers; and these forces are forcing us to change our attitude.

I don't think we would be that concerned with building systems if it wasn't for these external forces and so let us review first what these forces are and what their influence on the design process and on the construction industry is.

The first force, which is highly publicized, and nowadays is quoted by senators and congressmen, is the numerical growth of the whole population.

Now, the statistics are very impressive and they are particularly impressive when one looks at them in terms of the international scene; the United States and Canadian statistics suggest that the population will be doubled in about thirty-five to forty years. This, of course, means that the equivalent of every existing building, whether it is housing, hospitals or commercial development, would be built in the coming forty years in addition to what has to be built in order to replace obsolete construction which is probably three-quarters of the existing construction. If you look at these figures internationally, they are much more shocking.

The Indian figures are that the population of India will be doubled in thirty to thirty-five years, depending on how much you believe in the success of birth control programs. Urbanization, which India is experiencing now, will result in a high degree of migration and consequently to provide for new population as well as migration to cities, the Indians will have to house seven hundred million people in a period of about thirty to thirty-five years.

This statistical fact, this reality, is, I think, so fantastic that most of us, certainly I, don't feel that I can comprehend it. It is even more difficult to comprehend what that means to the building industry.

The usual correlary of this fact of numerical growth is that it affects building density. People say that to deal with population growth we need to build greater densities, which I don't think is the case at all. I think population growth has very little to do with densities in our urban environment. Where population growth is going to affect us in the construction industry is in the rate of construction. If we have to build at a rate that is four or five or six times the rate we are building now, and if we are dealing with an industry where the availability of hand labor is becoming more and more scarce, and where it is available, is more and more expensive; then it seems to me that just to cope with this accelerated rate of construction we are going to have to change our ways of building.

The second force affecting us is a political force, and in my opinion is the most powerful and important force. It is the result of political evolution which has been taking place over a number of decades, but is coming to a head right now; it is the fact that our political systems have evolved, (and I am talking about the political systems in any country today) in such a way that it is no longer possible for planner or architect to base an environmental solution on the idea that it should serve part of a minority of the population. Any environmental solution that we put forward, by the very nature of the political systems today has to be applicable to the total population. It cannot be limited to a portion of the population, because in no country today, and this I think is true of the countries of the West or the East, can government or the professions put forth solutions which are not universally applicable. This powerful force is bringing about the total change in our attitude to the design of our cities and to building itself.

The thinking of Buckminster Fuller, who I believe began this series, is really very, very significant. Forty or fifty years ago Buckminster Fuller saw that any environmental solution has to be universal; he made the connection to technology and stated very clearly that the only way of achieving a solution which is universally applicable is by using technology to the limit in achieving maximum efficiency of labor and material.

To illustrate what I mean by environmental solutions capable of general application I would like to use the example of the post-war development of housing

in the United States and Canada. The single-family house on its own lot in a typical suburban development, let's call it Levittown, was the predominant solution for a good portion of the population. With the perspective we now have we could see that the suburban boom was only possible because in its nature it limited itself to a certain portion of the population. Had the overall population, including lower income families, the families who remained in the center of the cities, been a part of that boom, then the expansion and the spread of the cities would have been two, three or four-folds what it was in the last twenty years, which as it was, was unmanageable. So that it was inconceivable for suburbia to have been created except as a solution to a part of a population.

The fact that suburbia remained a solution for part of the population has nothing to do with construction costs or anything like that. Public housing apartment dwellings still costs more than the typical suburban house. Rather it has to do with the fact that we created financing patterns and land use patterns and government administration patterns which made it inevitable that only a portion of the population could be part of that development, and that economic segregation would result.

The third force has to do with the combined aspects of our economy and our social structure that have brought about the metropolitan city. The metropolitan city, to generalize, is a result of two main forces. One is the necessity of business and industry to concentrate because of their inter-dependency on each other and on basic services which they find in metropolitan cities. The other concerns social forces. Modern man is very demanding in the variety of amenities and facilities expected in his daily life. It takes several million people to support the institutions and facilities we want. And so, we precipitate to the metropolitan city which offers us that kind of variety.

Both forces have brought about the metropolitan city, and it is in the structure and nature of the metropolitan city that we come to face the problem of density. (Density is not the result of the absolute number of people living in a country or in a region.) Our need to create greater densities is a byproduct of the form of our metropolitan city.

One has to make reference to the various suggestions or approaches that have been made by planners in recent years as they may affect density, because I believe that the degree of density to which we build and develop our cities is probably the most critical criteria in the development of building systems. Therefore, the question of whether we are going to predominantly build our cities at lower or higher densities is of the highest order and is a major influence on how our building industries are going to develop.

Let us explore whether there is any accuracy to the conclusion that much greater densities than we have today are going to be the predominant form of the development of our cities.

The first alternative, of course, is to resort to dispersal. If great dispersal took place in our cities, then we could assume the result could be lower densities and greater areas than the form of the city today. I believe that dispersal is and will continue to take place. Dispersal will particularly take place as a result of progress in ground urban transportation technology which will bring great changes in the coming ten to fifteen years.

Let us observe what is happening right now in the city: one could say that the traditional limit to city size, the distance that one can travel in one hour, is continuously expanding. The distance which a person could travel in one hour has traditionally limited the size of the city, so we have had cities five miles in diameter, and then with the car it was ten miles, and then as we built expressways it became forty miles. I think it is a fairly safe speculation to say that the one hour travel limit is going to greatly expand and that we will introduce systems of ground transportation that will move three, four and five hundred miles per hour in the next decade or two. We will develop methods of loading people on them, and relate one system to another so that they function as a total integrated system. This will expand the city so the city which is now forty miles in diameter may become four or five hundred miles long. Montreal to Toronto or Boston to New York or Los Angeles to San Francisco would become a single urban region where fifteen or twenty million people would belong to a single urban entity.

This dispersal, this expansion of the one hour travel limit, will not, however, affect density, because the nature of this expansion will be the expansion of concentrated developments rather than the dispersal of an even lower density as the suburban expansion has been.

This expansion, the result of increased mobility, is going to create a city which is structured as a necklace, a necklace of relatively dense developments. Now, if we accept that the kind of metropolitan city that we are moving toward will have fifteen million people in it, and if we assume that we will be able to expand the size of the city considerably, then what are the consequences? Let us take, for example, a linear city, which is say, three miles wide and has an average density of one house per acre, as Frank Lloyd Wright's Broad Acre's proposals. Adding the proportional area of non-residential facilities that we require, the city would be four thousand miles long, which I suppose is obviously unmanageable.

If we increase this density to an overall gross density of ten units per acre, which is about thirty or forty people per acre, then the city becomes three miles wide and four hundred miles long, which is already getting to be something we can manage. And then if we take it one hundred units per acre which is extremely high density, (much higher than Manhattan) we can have a city of fifteen million people three miles wide and forty miles long. I believe that it is inevitable therefore, that we must build much greater densities <u>as the predominant form</u> of development in our cities.

I don't mean by that that we are going to build greater densities than say Manhattan or the center of Boston or Montreal, because I don't think we need to, but we must remember that complementing the center of Manhattan we have

several hundreds of miles of very low density. The critical issue is, it seems to me, that as we increase density we have been reducing the amenities of life as compared to lower densities.

As densities have become greater, we have given less and less to the individual and so probably the most critical environmental issues of our time is how can we increase densities and at the same time either improve or at least keep the status quo of the kind of environment and the kind of amenities we require.

I suppose amenities is a weak and general word, but I can't think of a better one; one which stands for the needs and requirements that the individual must make on his environment.

The assessment of what will be the changes of the urban pattern as a result of increased densities are of tremendous importance to the concept of building systems and industrialized methods. Increased density will bring to an end the whole form of two dimensional urban development of streets and individual buildings. It seems to me that we have reached the point today where it is too inefficient to build individual buildings within a two-dimensional urban plan as independent entities from each other. It is just not possible to create the kind of environment that we want and still be operating within that straight-jacket.

We are reaching the point of the natural end of the individual building in the city; the city will become not the subdivision of land with buildings in it, but the subdivision of space. The subdivision of space will be constructed of continuous building systems, not individual buildings; and if we give ourselves this flexibility that we subdivide space rather than land, that we can mix land uses residential, commercial, and so on, we will be able to create a more efficient environment, that will work better and will achieve more in terms of the material and labor that goes into it. Each land use will then be complementing the other rather than fighting it, and the amenities that we can achieve in the environment will be greater, in the sense that they offer more choice to the individual than the lower density environment.

The tragedy of our time is that we have inherited the whole legislative system that has been developed over decades and centuries which is essentially rural in character and totally unrelated to our urban society, evolved at a time when the urban problems we face today didn't exist.

The ghetto, the exploding ghetto, which everyone is impressed with today, is a very dramatic illustration. Everyone is impressed with the problem of the ghetto, regardless of one's feelings about the solution; but a very predominant attitude amongst people today is that the problem of the ghetto is that not enough money has been diverted to a particular area within our economy and that if we became charitable about it and if we gave a little more funding and grants and so on, the problem is going to be solved. I do not think this is the case at all. I think that the ghetto is a symptom of a very critical and deep malady in the urban (and political) structure. It is only one symptom and in order to eliminate the ghetto, it is going to take much more than charity and a little bit of funding in Washington; it is going to take a basic change in our legislative system as it relates to the city. There are a number of examples that could be used to illustrate this:

Our whole municipal government structure is based on the fact that every small area should form its own government; it should be autonomous, and we have very little means by which to have these act together even when they have become a single urban region which functions as a single organism.

The ghetto is part of that. It is the byproduct of this problem. It is not possible to have an urban region which is, say, forty miles in diameter function properly if it is made up of fifty different municipalities who by nature are going to be concerned with their own interests.

They can't possibly be concerned with the whole region and give it priority over their own interests, and so one fundamental change that has to take place is that while on the one hand we ought to respect the desire of the majority of the population to live within a community which is small enough for them to identify with, at the same time, some kind of governmental expression of the urban region as it functions as an organic unit is needed, so that transportation systems and tax distribution and land and resource planning can take place.

Today the general attitude of each small municipality is to think of its own finances as if they were a separate entity. Some kind of mechanism has to be introduced where the tax base of a region is distributed to that total region rather than to just a small area within it.

Another example is our attitude toward land ownership and the whole legislative tradition behind it; when you own land, you do what you want with it.

It is yours; you, as an individual, should be able to do what you want with it. And this again, whether we like it or not, is in contradiction with the realities of a high density urban region. In fact, today it is just an illusion that you do what you want with your land. It is so restricted by zoning and bylaws, and its value so determined by these same factors, that it seems to me we are living in a kind of illusionary world. The consequences are clear: Land use cannot be determined individually; the use of land has to be determined publicly. If we accept that land use is determined publicly, perhaps we could develop new methods for dealing with it, where land is leased to an individual or a corporation for long terms to be developed, but every fifty or one hundred years the public has the opportunity to reassess the use of that land.

To repeat, our whole financing system of housing has inherent in its nature a creation of a ghetto, because you have one kind of housing financed privately from money off the market, and you have another kind of housing which is financed semi-publicly and semi-privately and is publicly guaranteed; you have another financial system that serves "moderate income," families with subsidized interest rates, and then, finally, you have

public housing in which rent is directly subsidized. If you happen to earn so many dollars, you fit into one project, and if you happen to earn five hundred dollars more, you qualify for the next category, and then if you make a thousand dollars more, you move out and go to another project. Each financing system has discouraged any kind of mix. So the public housing authority wants to build public housing and financing under title 221(d)3, and other FHA programs are separate communities. These are realities of today.

I am working on a prototype project in Washington (Fort Lincoln) right now which is a mixture of public housing and 221(d)3 housing, both specifications are exactly the same, the same room sizes, same materials, and yet I was asked to draw a lot line so that we can separate moderate income families from low income ones.

The overwhelming fact in any discussion of building today is that without exaggeration one can say that fifty percent of the entire population cannot afford, with its own earning power, to buy decent housing. If we consider that amongst the other fifty percent a substantial portion now buys housing in the low density peripheral part of the city, then this figure of those who cannot pay their way is bound to be going up unless something pretty drastic happens in the immediate future.

I have mentioned density, and will elaborate later why density has technical implications on building, but before I do that, I would like to discuss the effect of density on building economics.

For equal amenities,for the same living standards, for the same facilities,it seems that the greater the density, the higher the construction cost per unit area. This is a fact that is totally unrecognized by our legislators, by our housing authorities, and is probably not recognized by the public.

The fact is that the greater your densities the more dollars per square foot you are going to have to put into construction to achieve the same kind of amenities. Let me give you some specific examples. Consider a single family house, which offers some very real, basic amenities to the people who live in it, as a standard of measure. It gives the owner a certain degree of acoustic and visual privacy from their neighbors. You can carry on a fight and play loud music and have a party in single family houses, and the fact you have a brick wall and a six or ten foot space and another brick wall is good enough to give you pretty good sound separations. You can have open space -- a garden, in the single family house; and if you have a garden twenty by thirty feet, which is a pretty good garden, and the land is costing you fifty cents a square foot, then the garden cost is three hundred dollars. Compared with a multi-story, multi-family dwelling of any kind, the same kind of acoustic privacy, getting that kind of sound separation between two dwellers which are touching each other, is a major technical problem and probably costs two or three times as much as achieving it in the single family house.

If we want to provide a twenty by thirty foot outdoor space for a family, supplementing its indoor space, which seems to be a basic requirement for a family with three or four kids, then it is going to cost you five or seven dollars per square foot or four or five thousand dollars. So for equal amenities the cost increases as density increases, and the sooner we recognize that, the better off we are.

I haven't touched on such aspects as, say, fireproofing. When building low density, you can use certain materials which are less resistant to fire and have a totally different behavior pattern than materials that you have by necessity to use if you are building high density. When four or five thousand people are living in a building which is twenty stories high you have to give them an hour or two to get out if it is on fire, and it is not just a matter of compliance with a code, it is a real requirement.

Many of the very exciting examples of building systems which appeared in the last twenty years have not accommodated this problem. Buckminster Fuller's dymaxion house, one of the really visionary proposals for industrialized building, is not possible without very basic dramatic technical changes in our use and methods of fireproofing of metals.

We must conclude that, once we accept the fact that the social and economic forces which I mentioned earlier are causing us to increase density in the city, it is also going to cost us more to build the kinds of environment which we expect, and to me one subsequent conclusion is that the basic proportion of our gross national product that is devoted to the city and to housing is not enough; that we are going to have to increase the proportion of our gross national product which is devoted to the housing and urban services over what it is now. This would be very dramatically felt in the next ten years.

If we accept the fact that we are dealing with a continuous building of high density in the city, we then create new needs for materials and technologies. We must therefore determine what are the shortcomings of the way we build now and what changes can we anticipate or propose in order to improve the quality, the rate of construction and the cost of building?

Everyone would agree that industrialized housing, which makes full use of factory production and assembly line techniques that other industries have used, when it is applied to housing and other construction is going to reduce the cost of construction. But we must have industrialized housing in order not only to reduce cost, but just to keep our standards where they are, because of the question of density and because we are going to have to deal with the rate of construction that is unprecedented.

My own conclusions, which evolved in the process of working on the "Habitat" system and the preceding solution which led to it, was that the obvious way to

affect that kind of a change was to take the construction process and put it in the factory.

It seems to me that if you could take everything that happens in the field now in the individual building, and take ninety percent of it and put it in a factory, then you are establishing the circumstances where industrialization can take place.

Having come to that conclusion, I then came to the second conclusion, that the way of doing this was to break up the mass of a building into space cells; the space cell, which is a portion of the building, is a component, which can be made totally in the factory, prefinished in the factory and the only work we will have to do at the site is assembly.

The Russians, in studying the industrialization of building, came to the same conclusions in preference to plainer or panel systems, which is not a space cell. Out of these conclusions I evolved a certain modular system of space cells which can be theoretically a part of a house or a part of a school or a part of a hospital or a part of a highway section, and they are not restricted to any particular building type.

When we say "move construction into the factory," I think we mean much more than prefabrication in the conventional sense. I think a dangerous public belief is the idea that industrialization is simply prefabrication -- putting bigger panels together, which have been cast in the factory, so you may get a whole wall instead of making small bricks. This aspect of prefabrication is relatively insignificant, because putting housing into a factory is first of all adopting the organizational and production techniques of other industries, and that has to do with many more aspects of production than just the factory.

Look at the car industry or the aircraft industry and consider how they are organized. Galbraith in his book, "The New Industrial State," makes a keen analysis of what the organizational requirements of any industry are regardless of what its production is. One thing that we observe is that the nature of the industry and its corporate structure make it possible for the amortization of a very substantial percentage of its income in relation to the actual product itself into research, design, and tooling.

The aircraft industry can afford to put one or two billion dollars into a single aircraft prototype before it even puts it on the production line, and it is able to do so because it is the very nature of its organization which makes it possible for it to recover and amortize this investment over a very large market later on.

So effective is this capability that an aircraft designer does not work around existing materials; an aircraft designer works out specifications for needed materials and if they don't exist, the industry has the capability of developing them. With the construction of a building the designer is working around existing materials and the fallout of other industries.

The whole process of designing a product, designing the machinery which makes that product, and the manufacturing process is done by a single group under a single authority at the same time; so that when a window is designed for a particular car, its body is designed and the machinery for making them at the same time.

Consider a single family house designed by an architect; the going fee may be somewhere between five and ten percent; so an architect is expected to put a building together which functions properly and put his signature on and guarantee its performance and supervise it for five or ten percent of the cost of that product: In the case of a car, which in my opinion is a much simpler design problem than a house, ten or twenty thousand percent of the value of the car may be put into the design of that particular model, and so I don't know how one expects the architect to design a house which works, so they mostly don't, when the proportion of input of design, I mean the total design process both technical and formal, are so limited. Take the car industry and think what would happen if they operated the way the construction industry does?

G. M. would go to a designer and say, design a car for us, and he would open Sweets catalog for cars and start looking up what is on the market this year and pick up various components and make a set of drawings. G. M. would then go and call for public bids and some group that has had nothing to do with the first design stage is going to have to come and buy those components and make a car out of them. The assembly line will have thirty different unions working on it. If I learned one thing out of "Habitat" it was that you can't have an assembly line made up of thirty separate trades and six different unions; you just can't do it.

If you want to have an assembly line, it has to be a single administrative organizational body, and if you want to operate in the way other industries operate, then you have to accept that the building industry has to change its total organizational structure. The whole relationship between architects and engineers and contractors and manufacturers is totally obsolete. And unless in some form or another, there are alternatives as to what that form is, the architect and the engineer and the industrial designer and the manufacturer, the production expert and the contractor who is putting the thing together must work as a single group from the beginning within a single financial structure.

What kind of systems are we going to concentrate on? It is very fashionable amongst students today, and amongst some government officials particularly in England to say that building systems should not be closed systems, they should be open systems; every manufacturer should be able to make his own components that could be used by any designer in any system. Based on the experience that I have had, I believe that any attempt to develop an open building system at this time is going to delay the industrialization of building by about twenty years. The reason being that the problem of developing an open system is going to involve complex dimensional coordination of an order that the industry cannot meet. No industry has been able to operate on the basis of an open system. For example, a car is strictly a closed system; motors may be interchangeable and G. M. may buy the sparkplugs from a central source, but by and large the car is a closed

system; so is the aircraft industry. The problem of designing an open system is just infinitely more complex. Consequently, industry must first develop closed systems which are capable of manufacturing and once we achieve that, let's talk about open systems.

Finally I come to the third aspect of building systems and that is the design process, the form making process of a building system.

Today there is the illusion that industrialization of building is a guarantee for good environment, but industrialization of building will do no such thing. We could very well go through a process of industrializing building and we would have several of the great corporations going into the housing business in the same design process that has characterized other products made today. Our environment would be so bad that Kafka would turn over in his grave. We have examples to learn from: Much of the housing of Europe and the USSR, notwithstanding their efforts to industrialize building, were not implemented through an understanding of the environment. The result is an environment produced by precast boxes made in the factories--a frightening scaleless environment which lacks identity and which I am sure we would all rebel and react against.

It is characteristic of the design process today that it is highly arbitrary; fashion and style are predominant factors in the design process. One could say that fashion and style vary directly with the degree of arbitrariness in the design of the object. The more arbitrary, the more "fashion" becomes a factor. But in industrialized building a design decision which may have applied to a single building in the city, all of a sudden becomes a design decision that may affect five million people in thirty cities. The responsibility is incredible.

The whole process by which we determine the form of the environment becomes something that we must question very carefully. The approach to the design process as a system of determining the broad program, could be described best by the word "morphology" which has nothing to do with construction, but rather biology. Morphology is that science which deals with the reason why particular forms in animal and plant life are the way they are; it assesses the reasons how through evolution a particular form has become what it is; and how it relates to survival. But in order that we may gain some understanding of our environment, the design process must be considered as the morphology of the environment, the morphology of the city. What are the forces that are critical to the survival of the city considered as a living organism and how do we satisfy them in form of the city?

Perhaps making some analogies to natural form would clarify this. Each form in nature is shaped by a group of forces. The Nautilus shell has a certain spiral formation (which everyone considers to be beautiful) which is a direct result of its growth pattern. It must grow in such a way so that the proportion of its body and head are equal to the proportion of the opening in the shell itself. The only way it can do that is by logarithmic spiral growth, so that the growth pattern of the Nautilus results in this form (known as gnomonic growth).

Now, the city has a growth pattern, a very definite growth pattern. Inability to grow organically causes problems: The slums in the city are a result of expanding land use incapable of proportionally growing together - not age of building.

Another analogy could be the leaf pattern of plants; plant life in moderate climates, where it requires a great deal of sun, develops large leafs and these leaf formations are arranged in such a way that they absorb the maximum sunlight. In contrast plants in hot climates evolve contrasting forms: The olive tree has a silver side and a dark side: The silver side rotates so as to always face the sun and that is true of some cactus species as well.

The form of leaves and their relationship to each other has direct relationship to sunlight and climate. The great variety of plant life is partially related to this force of light.

There is an added aspect to the structure of the environment which is not physical, which cannot be found in biological form, and that is the psychic structure of environment. If people demand of their environment a certain quality which gives identity to their dwelling, than it becomes a morphological necessity in the design of houses. Then, if you design a building which is a steel and glass facade forty stories high of equal unidentifiable cells, this does not fulfill the requirements of giving identity.

Somehow we are going to have to come to understand the complex program of environment, an expansion of the word "functionism," a word so badly misused in past decades. There was a great preoccupation with the word "functionalism," at the turn of the century. To some of the concepts of past decades there has been a reaction. Many architects in North America are part of that reaction - a reaction associated with functionalism.

Phillip Johnson has said, "everything is possible in art and in architecture today." I think the statement suggests a certain freedom which in its nature suggests that there is arbitrariness. I don't think that everything is possible; there are very few alternatives to a given environmental problem. Efforts must be made to define the problem in its broadest sense and limit the alternatives. It is not just a question of "expressing structure," a term which is caricatured by exposing a frame that holds the building up, but of considering total structure, physical and psychic.

(At this point, Mr. Safdie showed a series of slides on the development of a number of building systems, including Habitat, low and moderate income housing in Puerto Rico, and the Student Union in San Francisco.)

I suppose the most fundamental question that we face today is that we require very fundamental changes in our system at many levels, yet everyone is familiar with the resistance to this kind of change.

And so the question arises as to how are we going to be capable of being able to bring about certain changes? If we say that the relationship between the architect and industry is obsolete; how do we change it?

If we say that the building industry unions are reactionary in the sense they bear no relationship to the building process as we would like it to be; how do we bring the unions into it so that they reconsider their position?

And it seems to me that there is only one way, and that is by building prototypes of a very large scale and in great numbers. When you build prototypes, particularly when you put sufficient funds behind them, then you are forcing everybody who is part of it to reconsider, to set precedents; when you bring industry and contractors and a group of architects and engineers together and give them the job of building a community then you must also accept that they are going to go wrong fifty percent of the time. This is true of any prototype and research. It is a way in which you set precedents continuously, and I think that certainly the Canadian government feels that today, four years after they made the decision that Habitat as a prototype was a worthwhile venture on which to spend $20,000,000. Government policy should be, instead of spreading all its research funds in ten thousand different grants of small measure, to concentrate all its funds into building a few very large prototypes in which the best talents of the industry and the professions are put to work together. Thank you.

QUESTION PERIOD

FROM THE FLOOR: I think some months ago we had Dr. Eberhard here from the National Bureau of Standards Institute of Applied Technology, and he mentioned that one of the greatest problems was mobilizing the housing market in order to enable the economy that could come from mass production of the individual units, and he mentioned this as such an overwhelming problem that he and his group in making evaluations didn't think this would ever be possible looking ahead a decade or two.

MR. SAFDIE: What is meant by organizing the housing market?

FROM THE FLOOR: As I recall, he came up with a figure of six hundred thousand units a year for tooling up this kind of industry bringing it to a scale that would be economical. In order to produce, distribute and sell these six hundred thousand units you have to have an organized market, and he felt that this wasn't possible.

MR. SAFDIE: While I agree in principle that it would be very nice to be able to amortize over six hundred thousand housing units, it is possible to have very serious ventures into industrializing with one hundred thousand units, and even ten thousand units. You are not going to be able to do with ten thousand units what you could with five hundred thousand, but this is a question of evolution.

Now, the other aspect is the market. If one of the big corporations went in the housing business today and issued a catalog of what they have to offer which builders could buy and assemble on particular sites, in my opinion, they could sell them as fast as they could make them.

I think it is nonsense to say that you don't have a market. I know myself (I am not in industry) but I get maybe five letters a week from builders thinking Habitat is a building system that is shippable and marketable from different cities stating they have, say, a hundred acres and we would like so many units, "please give us a quotation." (Laughter.)

The market is there. The problem is that there is a separation in terms of thinking between the technical development of systems and the environmental aspects of systems. Very often people would say prefabrication houses won't sell, and then they start giving you the examples where inadequate design resulted in public rejection. The basic concept of the industrialized housing has never been rejected; what has been rejected is the garbage that has been produced using industrialized systems. So, unless we can produce a system which is industrialized but also offers amenities in response to what people want, we just won't have a market. The market is there.

FROM THE FLOOR: Speaking of the garbage business being produced; several weeks ago Paul Rudolph spoke at Harvard and his lecture was entitled "Mobile Homes." I am curious, given an industry which is tooled up already for prefabricating living units of some sort, I am curious about your reaction to the virtues or deficits of using such an industry to prefabricate architecturally usable things, and also could you say beyond that in terms of the load bearing nature of your units, how high could you go with a module you used in the student project?

MR. SAFDIE: I am fairly familiar with what Rudolph is doing, because we are doing projects side by side in a demonstration program in Washington at Fort Lincoln where the redevelopment land agency has taken a three hundred acre site and they have three small experiments going in the corner. Rudolph is doing one hundred and twenty units and Harry and my office are doing one hundred and twenty units each using a particular technology.

I think Rudolph is basically right that the purchasing power of that particular industry is of interest. I think the tooling facilities are not as important, because I think that they are very specific to a particular kind of a product.

There is no doubt that the module in terms of its proportions and so on lends itself very well

to a space cell system, and I think that Rudolph in the way he groups them produces a very habitable environment, but it is a good example of where a particular industry which has developed particular materials and methods of joining them for particular requirements, i. e., moving things on the highway, doesn't quite apply to the different problem of permanent housing on a permanent site.

In Washington Rudolph's solution which is the skin of a trailer with an asbestos cement skin outside and wood joist is limited to three stories. He can't build higher than three stories and that to me is a technical restriction that only applies itself to fairly low density solutions.

Now, in New York he has come up with a scheme in which he suspends modules, and to the extent that he can solve the fireproofing problem, his system there becomes very similar to the things I have discussed today.

Whether they are suspended or supported in compression, I think, is a question of economics. I would consider compression up to sixteen or seventeen stories without any question. In New York I am designing thirty stories in compression, but it is in a triangular space frame.

FROM THE FLOOR: If I may refer to India which you made reference to; it seems to me that in a country where the population grows approximately three percent per year and gross national product has to grow approximately four percent a year just to maintain the same rate of growth, it is very difficult, if not impossible, to rely on a capital intensive development which utilizes machinery to a large extent and labor to a lesser extent. So, it becomes rather redundant to suggest, in my opinion, a capital intensive housing development while ignoring the fifteen percent of the low skilled people, and the idea perhaps should be to utilize this labor by using labor intensively rather than using imported machinery.

MR. SAFDIE: In general terms I disagree with you. I have been to India and looked at what is being done there, particularly in the government research groups and they share your view. They say that they have a brick industry which utilizes a great deal of labor and what ought to be done is try and use the maximum possible hand labor rather than industrialize it.

They go on to say that if you industrialize, you create unemployment. Now, I think this is a very shortsighted view of the total picture, because to start with, I don't think the traditional methods of India, say handmade brick and so on, can deal with the numbers they have to build for.

Secondly, I think that these methods are related to the rural environments and as they urbanize, which they are, urbanizing very much in the western pattern, a lot of these methods become less applicable.

Now, the argument that industrialization in building will cause unemployment is very similar to the argument that is put forth in this country against automation which is also a shortsighted view, because automation couldn't possibly cause unemployment in the long run. In fact, all it will do is release people so that they can be employed in other industries or services. If you look at India as an industrializing country, industrialization of buildings would release labor that would be needed in other industries in the long run.

Now, that does not mean that our technology is necessarily meaningful to them right now. For example, a solution in India may be that you make a modular unit out of the thin tube and spread jute on it and spray coconuts mixed with local cement, but this is still technology.

I think they have to evolve their own technology in terms of their own requirements, but I do believe that there is an urgent need in India to industrialize building.

The biggest question is one of broader policy in a country that has such a pressure of priorities on capital in its total economy. Production is not catching up with the rate of growth of the population. Do you take capital expenditure and put it into housing which is a consumer product, or do you put it into heavy industry? The Russians decided in the thirties they weren't going to do any such thing, and they had the kind of government that could enforce it. I'm not sure that this same process will take place in India. I think there will be gradual growth of consumer and heavy industry at the same time and, therefore, it will be much slower, but less painful.

That again does not mean that one has to be dogmatic about it. I think there is a transitional period and there should be many methods introduced in India today which use labor and again try to improve on efficiency.

I saw one highway being built in India three hundred miles long and they had large rocks piled up every several hundred feet and you saw women there with a small hammer breaking those rocks into fine gravel, and that will take fifteen years, I'm told. Nothing in the world will make me believe that this is good for the economy of that country.

FROM THE FLOOR: In the short run, for these people to be making a living, it is more important for this woman to earn two pennies a day rather than import heavy machinery with rather expensive foreign exchange and substitute this labor with machinery.

MR. SAFDIE: That depends upon what the woman will be doing the following week on her new job. There really are many other jobs and if the Indian economy is to grow, then it will offer new jobs. It is inherent in the industrialization process that it will create continuously new jobs. Japan is a good example.

FROM THE FLOOR: Do you think that the changes which you suggested are likely to come about in this country and in India--and in how many years?

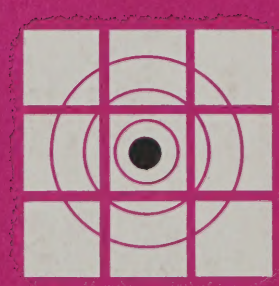
MR. SAFDIE: The problem here is that there is a certain legislative and political tradition. Perhaps three or four years ago I would have said, well, that just won't happen in the United States for maybe thirty or forty years; but I think many things are changing.

First, I think that there is a tremendous political pressure by major groups and that pressure is a real political force for the first time.

I think that is certainly loosening up a lot of resistance to change as compared with three or four years ago, and I think that as a result many considerations such as the legalistics of our municipal structure and the financing of housing are going to be reconsidered. The fact that you open every newspaper today and read about it, and every magazine has articles about it shows that it has become a major political issue and, consequently, I think changes are going to be very rapid and you will see fantastic changes in six or seven years.

The problem of India is totally different. It is a problem of the existence of an organization with a force and determination to do these things. It is such a dissipated bureaucracy that it seems to me, and this is a personal opinion, that it is going to take a political shake-up at a much higher level to affect the environment.

The whole political system doesn't appear to be able to deal with it efficiently enough. I think the problem there is not one of the environment, it is one of total capability of the system to deal with the economic growth which must, first of all, feed people.



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